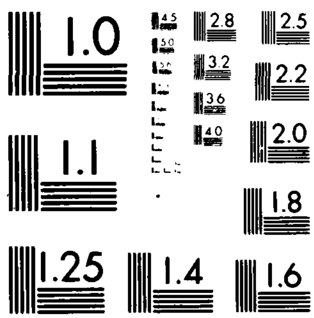
AD-A109 984 CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT F/G 13/2
AN ASSESSMENT OF WATER QUALITY IMPACTS OF MAINTENANCE DREDGING --ETC(U)
JAN 81 D D ANDERSON, R J WHITING, B JACKSON

UNCLASSIFIED NL

1 OF 3
AD
A 109 984



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

PHOTOGRAPH THIS SHEET

AD A109984

DTIC ACCESSION NUMBER

LEVEL Army Engineer District St. Paul, MN

INVENTORY

An Assessment of Water Quality Impacts of Maintenance Dredging on the Upper Mississippi River in 1978 Final Rept., Jan. 81

DOCUMENT IDENTIFICATION

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS	GRA&I	☒
DTIC	TAB	☐
UNANNOUNCED		☐
JUSTIFICATION		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
A		Code 23

DISTRIBUTION STAMP

DTIC COPY INSPECTED 3

DTIC ELECTE JAN 25 1982 S D

D

DATE ACCESSIONED

01 20

DATE RECEIVED IN DTIC

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDA-2

DTIC FORM OCT 79 70A

DOCUMENT PROCESSING SHEET

AD A100984

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) AN ASSESSMENT OF WATER QUALITY IMPACTS OF MAINTENANCE DREDGING ON THE UPPER MISSISSIPPI RIVER IN 1978.	5. TYPE OF REPORT & PERIOD COVERED Final Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dennis D. Anderson Robert J. Whiting Barbara Jackson	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Army Engineer District, St. Paul Environmental Resources Branch 1135 USPO & Custom House St. Paul, MN 55101	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U.S. Army Washington, D.C.	12. REPORT DATE January 1981
	13. NUMBER OF PAGES 187
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dredging
Sediments
Water quality

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In 1978, the St. Paul District, Corps of Engineers, monitored five dredging operations at various locations on the Upper Mississippi River, including three hydraulic dredging operations and two mechanical (clamshell) dredging operations. All five studies were conducted in areas with relatively coarse sediments. Overall, with the methods used for disposal of the dredged material at the five sites studied, no major degradation of water quality was evidenced for either the mechanical (clamshell) or hydraulic dredging and disposal operations.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Bottom sediment samples from many historical dredging sites were analyzed for bulk chemistry, particle size distribution and settleability. Frequency of dredging at a site did not appear to be a major factor in determining the degree of contamination. High levels of contaminants were closely associated with the finer sediments. Sites in and immediately downstream of the Twin Cities metropolitan area contained the most contaminated sediments.

AN ASSESSMENT OF WATER QUALITY IMPACTS OF MAINTENANCE DREDGING ON THE UPPER MISSISSIPPI RIVER IN 1978

by

Dennis D. Anderson
Robert J. Whiting
Barbara Jackson

Department of the Army
St. Paul District, Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101

January 1981

ABSTRACT

In 1978, the St. Paul District, Corps of Engineers, monitored five dredging operations at various locations on the Upper Mississippi River, including three hydraulic dredging operations and two mechanical (clamshell) dredging operations. Four of the studies (two for mechanical and two for hydraulic) monitored only turbidity and suspended solids because a previous study (GREAT I WQWG, 1978) indicated that these parameters are useful indicators of chemical and microbiological impacts on water quality. The other study monitored the physical, chemical, and microbiological changes in water quality resulting from a hydraulic dredging operation. All five studies were conducted in areas with relatively coarse sediments (less than 10 percent silts and clays).

In the four turbidity and suspended solids studies, no changes or only minor changes in water quality were found to result from either the hydraulic or clamshell dredging activity. The study that monitored the effluents from a confined on-land disposal area indicated slight elevations in turbidity and suspended solids but noted that these levels had returned to ambient within 1000 feet downstream of the disposal area.

In the study which also monitored chemical and microbiological parameters, no significant increases below the hydraulic cutterhead were evidenced for any of the physical, chemical, or microbiological parameters investigated. The effluent from the confined on-land disposal area contained concentrations of some parameters (especially iron, manganese, and the physical parameters) that exceeded the pre-dredging and upstream control values. However, only iron and manganese were found to be significantly higher downstream of the disposal pipe than in upstream control values. Daily fluctuations in concentrations for most of the parameters were fairly substantial and tended to mask any impacts caused by dredging.

Overall, with the methods used for disposal of the dredged material at the five sites studied, no major degradation of water quality was evidenced for either the mechanical (clamshell) or hydraulic dredging and disposal operations.

In 1978, a bottom sediment reconnaissance was conducted for many historical dredging sites. All sediment samples were analyzed for bulk chemistry, particle size distribution, and settleability. Location on the river and the amount of fine materials (silts and clays) were found to strongly influence contaminant levels within the main channel of the river. Frequency of dredging at a site did not appear to be a major factor in determining the degree of contamination. Sites in and immediately downstream of the Twin Cities metropolitan area contained the most contaminated sediments. High levels of contaminants were closely associated with the finer sediments. Most of the sediments sampled were coarse, with 85 percent of the sites having less than 10 percent silts and clays and most having less than 4 percent.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

BACKGROUND

Maintenance of a 9-foot navigation channel on the Upper Mississippi River is a Federal activity authorized by the River and Harbor Act of 1930 and other statutes. As part of this maintenance project, the St. Paul District, Corps of Engineers, performs annual maintenance dredging of the navigation channels to remove accumulated sediments which prevent safe vessel passage. Disposal of this dredged material is regulated under Section 404 of the Clean Water Act of 1977 (33 U.S.C. 1344) which provides authority to the States, as well as to the U.S. Environmental Protection Agency, to participate in the regulatory process. The research presented in this report is the result of an agreement between the Minnesota Pollution Control Agency and the St. Paul District, Corps of Engineers, to conduct water quality monitoring and testing in connection with the 1978 maintenance dredging season on the Upper Mississippi River.

DREDGING STUDIES ON THE UPPER MISSISSIPPI RIVER

A very limited number of studies are available on the effects of dredging upon the Upper Mississippi, Minnesota, and St. Croix Rivers. One study conducted by the Corps of Engineers (1973) on the Minnesota River monitored turbidity changes resulting from a clamshell operation. In the study, turbidity tripled 100 feet downstream of the dredge. However, 0.8 mile downstream of the dredge, surface turbidity had returned to ambient and bottom turbidity was returning to ambient levels.

Another study conducted in 1973 monitored a hydraulic dredging operation in Pool 8 of the Upper Mississippi River (Corps of Engineers, 1974) and reported a significant increase in turbidity, nitrate nitrogen, and nitrate nitrogen resulting from a hydraulic dredging operation and subsequent dredged material deposition. In addition, significant numbers of sediment-bound fecal coliforms were released to the overlying water column and to downstream areas (Grimes, 1975).

However, in a study (Held, 1978) conducted in 1974 on a hydraulic dredging operation at the same site, increases in turbidity, nitrate nitrogen, nitrite nitrogen, and other chemical parameters were not observed. In addition to monitoring water chemistry, various biological (fisheries and benthos) and physical (particle size distribution) variables were measured prior to, during, and after dredging. The author concluded that the disposal activity during 1974 produced no measurable effects on any of these variables. However, the author did speculate about the reasons for the negligible impacts: the small dredging job; the dredged material that was not allowed to enter backwater areas; and the variance of the baseline data, caused by annual, seasonal, and diel fluctuations.

In a cursory study, the Minnesota Pollution Control Agency (1975a) found that oil and mercury concentrations in the water column increased below a hydraulic dredging operation near Richmond Island in Pool 7. Turbidity and suspended solids levels were found to be above Minnesota State effluent standards in the disposal island runoff. PCB's were also detected in one of the samples from the disposal island runoff, indicating a potential for resuspension of PCB's from dredged sediments. However, the MPCA concluded that major degradation of the Mississippi River below the hydraulic dredging operation was not evident.

Most of the major studies of the water quality impacts from dredging and disposal upon the Upper Mississippi River have been conducted in the lower portion of Pool 2. Because of its location (immediately downstream of the Twin Cities area), this area contains sediments more contaminated than those found in most of the Mississippi River (GREAT I WQWG, 1978). Thus, in reviewing the following four studies, please note that they cannot be considered representative of the impacts on water quality for areas with less contaminated sediments.

One study conducted by the Minnesota Pollution Control Agency (1975b) in this area monitored the effects of clamshell dredging. Increases in concentrations below the clamshell dredging operation were noted for suspended solids, turbidity, 5-day biochemical oxygen demand, zinc, and iron. Suspended solids, turbidity, and zinc returned to background levels within one-quarter mile downstream, but BOD_5 and iron concentrations had not returned to background within 1 mile below the operation.

Another study also monitored a clamshell dredging operation in the lower portion of Pool 2, at Boulanger Bend (GREAT I, WQWG, 1980b). In this study, water quality impacts were greater in the disposal plume than in the dredge plume and greater near the bottom than near the surface. In some plume samples, proposed MPCA water quality standards were exceeded for iron, mercury, ammonia, turbidity, dissolved oxygen, and fecal coliforms; but, in almost all cases, ambient levels of these parameters were already in excess of standards.

Turbidity levels had returned to background within 1,000 feet downstream of the dredge and disposal site. Relatively poor correlations between bottom and surface concentrations of parameters were observed in this study, and between physical (turbidity and suspended solids) and biological-chemical parameters. In the Boulanger Bend study, the use of color and color infrared photography as a monitoring technique was also explored. The study showed that this technique was effective in determining the areal extent of surface turbidity plumes, although it could not predict overall water column impacts since relatively poor correlations were found between bottom and surface concentrations of parameters.

Another study conducted in Lower Pool 2 (in conjunction with the GREAT I (1978a) monitoring study at Grey Cloud Slough) monitored a hydraulic dredging operation (Lee, 1977). A major emphasis of this study was to field test the predictability of the elutriate test on release of contaminants from sediments. In general, metal concentrations in the disposal discharge were comparable to those obtained from elutriate tests. However, nitrogen and phosphorus compounds generally were not comparable. In the field study, increased concentrations in the disposal plume were noted for soluble iron, manganese, nickel, and zinc. In addition, aldrin, pp'DDE, op'DDE, and PCB's were detected in water samples taken directly from the discharge point. This study also showed that turbidity had returned to background levels within several hundred meters of the disposal.

For the same study, acute toxicity (96-hour) bioassays were conducted on Daphnia magna, using elutriate and dredge discharge waters. In both the elutriate and dredge discharge waters, contaminants were not found to be released in quantities sufficient to be adverse to Daphnia magna.

The GREAT I WQWG conducted a study on hydraulic dredging and disposal (beach nourishment) near Grey Cloud Island in Pool 2 (GREAT I 1978a). During this study, turbidity and suspended solids returned to background levels within 1 mile downstream of the disposal island. Chemical and microbiological parameters closely correlated with turbidity and suspended solids, and generally returned to background levels within a short distance from the disposal runoff. Most parameters increased in concentration from above to below the dredging and disposal operations, but ambient fluctuations in the river water were, in many cases, greater than fluctuations caused by dredging and disposal. Proposed Minnesota Pollution Control Agency water quality standards for arsenic, chromium, lead, mercury, manganese, PCB's, and suspended solids were exceeded only in a limited area immediately downstream of the disposal runoff.

Cursory examinations of methods for minimizing disposal impacts from hydraulic dredging operations were performed by Claflin (1976). The use of polymer injection and silt screen were found to have only limited success.

A study conducted in 1977 (Marking and Bills, 1977) was aimed at assessing the acute effects of burial upon three species of freshwater mussels by dredged sediments. Two of the species studied required burial by 7 inches or more of sand or silt to prevent the emergence of 50 percent of the test populations. For the other species, pig-toe (Fusconaia flava), 4 inches of silt prevented the emergence of 50 percent of the test population. It should be noted, however, that the study only assessed the acute effects of single dredge spoil overlays on clams, not the effects of rates of deposit, adaption to new substrates, migration to new substrates, or long-term effects on the survival of clam populations.

OBJECTIVE OF THE 1978 MONITORING PLAN

The overall objective of the 1978 monitoring plan was to provide further information on the water quality impacts of dredging and disposal operations on the Upper Mississippi River. The data collected in 1978 will be used for short-range river management and will provide additional information for the development of long-range planning and establishment of applicable dredging standards.

Among the studies that the Corps performed in 1978 was a comprehensive water quality monitoring study at Wild's Bend Dredge Cut (River Mile 730.4). Conducted in an area thought to have relatively clean sediment, this study monitored the physical, chemical, and microbiological changes in water quality resulting from a 20-inch hydraulic dredging operation and the subsequent effluent generated from a confined on-land disposal site.

Changes in turbidity and suspended solids resulting from dredging operations were monitored at four sites. Two of the studies monitored clamshell dredging operations while the other two monitored hydraulic dredging operations.

In addition to monitoring water quality impacts of dredging and disposal operations, sediment studies were conducted in 1978 to assess potential impacts of maintenance dredging on the Upper Mississippi River. As part of the 1978 sediment studies, a bottom sediment reconnaissance survey treated the navigation system as a whole, emphasizing specific sites. For this survey, sediment samples were analyzed for bulk chemical constituents, particle size, and settleability.

The other portion of the 1978 sediment studies consisted of suspended particulate and solid phase bioassays. Using four sediment types from the Upper Mississippi and Minnesota Rivers, the bioassays employed species indigenous to the Upper Mississippi. The four sediment sampling sites were chosen on the basis of their similarity, in respect to the large amount of fine material (silts and clays) and contaminants present at these sites. The bioassays (conducted by the Environmental Effects Laboratory of the Waterways Experiment Station (WES), Vicksburg, Mississippi, in a joint effort with the St. Paul District, Corps of Engineers) assessed both acute toxicity and bioaccumulation potentials. This portion of the 1978 monitoring is not contained in this report but has been published by WES as a separate report, "Biological Assessment of Upper Mississippi River Sediments" (see "References" section for full citation).

OVERALL SUMMARY

In 1978, five dredging operations were monitored at various locations on the Upper Mississippi River, including three hydraulic dredging operations and two mechanical (clamshell) dredging operations. Four of the studies (two for mechanical and two for hydraulic) monitored only turbidity and suspended solids because a previous study (GREAT I WQWG, 1978) indicated that these parameters are useful indicators of chemical and microbiological impacts on water quality. The other study monitored the physical, chemical, and microbiological changes in water quality resulting from a hydraulic dredging operation. In all cases, disposal of the dredged material occurred on land. For the mechanical (clamshell) dredging, on-land disposal involved direct unloading from barges and therefore only the clamshell (dredging activity) was monitored. For the hydraulic dredging operation, the dredged material was disposed into a confined on-land disposal area, with a drop structure and culverts to allow the effluent to return to the river after a short retention time. Therefore, both the hydraulic cutterhead and the effluent from the confined on-land disposal area were monitored. All five of the studies were conducted in areas with relatively coarse sediments (less than 10 percent silts and clays).

In the four turbidity and suspended solids studies, no changes or only minor ones in water quality were found to have resulted from either the hydraulic or clamshell dredging operations. Where minor elevations in turbidity and suspended solids were found, it was usually by only 1 or 2 NTU's and 2 to 7 mg/l, respectively. The one study that monitored the effluents from a confined on-land disposal area indicated a slight elevation in turbidity and suspended solids but noted that these levels had returned to ambient within 1000 feet downstream of the disposal area. In the four studies, location on the river greatly influenced ambient levels.

In the study which also monitored chemical and microbiological parameters, no significant increases below the hydraulic cutterhead were evidenced for any of the physical, chemical, or microbiological parameters investigated.

The effluent from the confined on-land disposal area contained concentrations of some of the parameters (especially iron, manganese, and the physical parameters) that exceeded the pre-dredging and upstream control values. However, iron and manganese were the only ones found to be significantly higher downstream of the disposal pipe than upstream control values. Because iron and manganese are ubiquitous on the Upper Mississippi River, they will probably show some reaction in most dredging operations. Elevations in concentrations of some nutrients were found. However, these were limited to the area immediately adjacent to the disposal area, indicating that very rapid settling and dilution occurred at the disposal site.

Daily fluctuations in concentrations for most of the parameters were fairly substantial and tended to mask any impacts caused by dredging. Overall, with the methods used for disposal of the dredged material at the five sites studied, no major degradation of water quality was evidenced for either the mechanical (clamshell) or hydraulic dredging operations. However, it should be noted that all five of the studies were conducted in areas having relatively coarse bottom sediments and may not be indicative of dredging finer sediments.

In 1978, a bottom sediment reconnaissance was also conducted. For the sediment reconnaissance, the Upper Mississippi River was segmented into five general sampling zones. Zone I consisted of the reach of the river from the Head of Navigation to the High Bridge (Smith Avenue Bridge) in St. Paul. Zone II consisted of pollution sinks which were defined from previous sediment data as contaminated and included the lower portion of Pool 2 and the Head of Lake Pepin in Pool 4. Zone III consisted of the stretch of river from Locks and Dam No. 2 at Hastings, Minnesota, to the Head of Lake Pepin. Zone IV consisted of the area below Lake Pepin to Locks and Dam No. 5A. Zone V consisted of Pools 6-10.

Within each of these five general zones, historical dredging sites to be sampled were selected on the basis of frequency of dredging: frequent, occasional, and infrequent. At each dredging site selected, a sample was collected from each of the coarsest and finest portions at the site. Each sediment sample was analyzed for bulk chemical constituents, particle size distribution, and settleability of the bottom material upon agitation with ambient river water.

The nature of the data and the scope of this study did not allow the precise estimation of average levels present, but the data were adequate for ranking by zones on levels of contamination. Zones I and II were most heavily loaded with contaminants, while Zones III, IV, and V were substantially lower. Zone V, the farthest from the major source of pollutants, the Twin Cities metropolitan area, was the least contaminated overall. Contamination by biocides and polychlorinated biphenyls was primarily limited to Zones I and II. Detectable levels or high levels of metals and nutrients were mainly found in Zones I and II.

Very high levels (and, in some cases, detectable levels) of contaminants were closely associated with high levels of fine materials (clays and silts) in the sediments. Frequency of dredging at a site was less important as a factor than either zone designation or the amount of fine material in determining contaminant levels.

Strong evidence was present in the bulk chemical data of the influence of point sources of chemicals.

Most of the sediments sampled were coarse, with 85 percent of the sites having less than 10 percent silts and clays and most having less than 4 percent. Settleability results were found to vary, depending on the particle size distribution. At the five sites where water quality monitoring studies were conducted, particle size distribution was generally similar to that at many of the sites sampled in the sediment reconnaissance. This finding indicates that similar dredging operations at these sites would have similar water quality impacts, especially the physical impacts on the water column. Chemical impacts on water quality, however, may vary depending on a specific site's location in relationship with source of contaminants

COMPREHENSIVE WATER QUALITY MONITORING STUDY AT WILD'S BEND DREDGE SITE (RIVER MILE 730.4) ON THE UPPER MISSISSIPPI RIVER

OBJECTIVE

The objective of the study was to assess the areal extent of water quality changes resulting from a hydraulic dredging operation, and any effluent generated from the subsequent disposal of the dredged material in an area of relatively uncontaminated sediments below Lake Pepin of the Upper Mississippi River.

METHODS

DESCRIPTION OF SAMPLING SITE

Wild's Bend dredge site is located at river mile 730.5 of the Upper Mississippi River. The area has been dredged approximately every 3 years from 1956 to 1977, with volume dredged per job ranging from 14,000 to 63,000 cubic yards. Sediment deposition occurs in the area because of the sinuous nature of the main navigational channel through this stretch of the river.

During the 1978 maintenance dredging season from 23 August to 1 September 1978, the 12-inch hydraulic dredge DUBUQUE dredged 11,566 cubic yards of material at Wild's Bend. The 20-inch hydraulic dredge WILLIAM A. THOMPSON finished the dredging job between 21 September and 25 September 1978. During 1978, the two dredges removed 26,188 cubic yards from this site to maintain a depth of 11 feet.

The disposal site was a diked containment area above the ordinary high water mark at river mile 730.5 on the left descending bank in Wisconsin. The diked area involved approximately 8 acres which allowed for an inside capacity of 60,000 to 80,000 cubic yards.

EXPERIMENTAL DESIGN

Sediment. On 19 September 1978, prior to dredging, eight sediment samples were collected with a modified 9-inch by 9-inch Ponar dredge (a modified dredge, painted with a special non-contaminating paint and fitted with a fine stainless steel screen) from the dredge cut (refer to Figure 1). Of the eight sediment samples, one was analyzed for settleability, four for total particle size, and eight for microbiological and chemical parameters.

Background Water Samples. On 19 September 1978, before the dredge was in place, ten water samples were collected from the area to be dredged near Wild's Bend (river mile 730.4) on the Upper Mississippi River. The water samples were collected from five sites and at two depths, 1 foot above the bottom and 1 foot below the surface (refer to Figure 1). The water samples were analyzed for physical, chemical, and microbiological components.

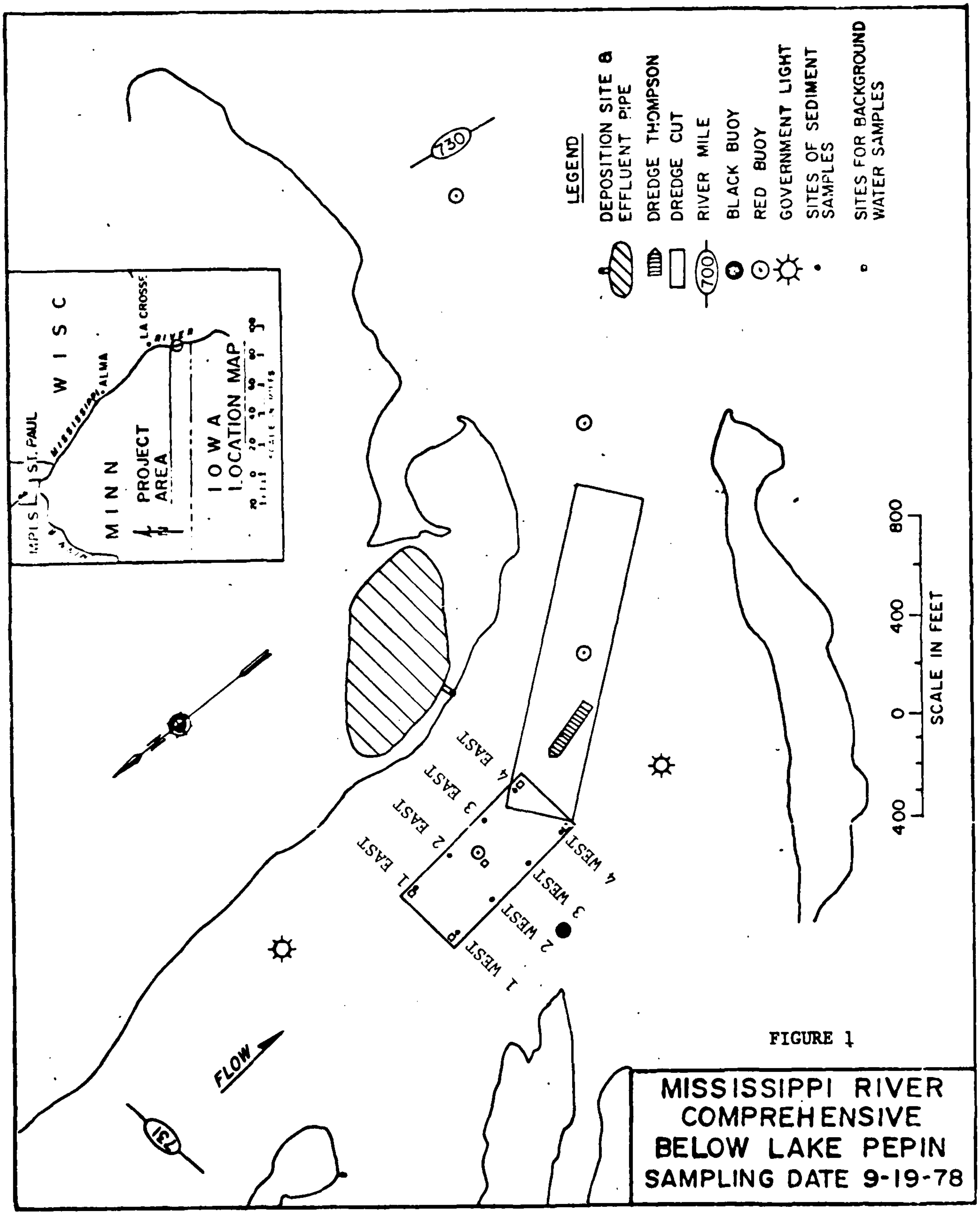


FIGURE 1

MISSISSIPPI RIVER
COMPREHENSIVE
BELOW LAKE PEPIN
SAMPLING DATE 9-19-78

Areal Extent. The water sampling for the monitoring of the water quality impacts of hydraulic dredging of the WILLIAM A. THOMPSON and the subsequent effluent from the confined on-land disposal was broken down into two phases. The first sampling phase occurred on 21 September 1978 and was aimed at assessing the water quality impacts of the hydraulic cutterhead (refer to Figure 2). Three sampling sites were positioned 1100 feet upstream of the dredge to serve as controls. Two sampling sites were positioned immediately adjacent and on either side of the hydraulic cutterhead. An additional three sites were positioned 800 feet downstream of the cutterhead. At each of the sites, water samples were collected at two depths, 1 foot from the bottom and 1 foot below the surface. Physical, chemical, and microbiological analyses were conducted on all water samples.

The second phase of the water sampling occurred on 22 September 1978 and was aimed at assessing the water quality impacts resulting from effluents from the confined on-land disposal site. Three sampling sites were positioned on each of six transects located 100, 200, 300, 400, 950, and 1650 feet downstream of the disposal site. In addition, two sampling sites were positioned near the back end of the dredge. The dredge at this time was located upstream of the disposal site (refer to Figure 3). Two control samples were also positioned upstream of the disposal pipe and the dredge. At all but four of the sites, water samples were collected at two depths, 1 foot from the bottom and 1 foot from the surface. The four sites not sampled at two depths were those located closest to the disposal pipe (on transect 100 and 200 refer to Figure 3). These four sites were located in shallow water. In addition to the above samples, two samples were collected directly from the effluent pipe at different times during the sampling period. Physical, chemical, and microbiological analyses were conducted on all samples except those depicted in Figure 3 , where some parameters were deleted because of problems with contractors supplying the required number of appropriate containers.

All water samples analyzed for PCB's and pesticides were collected with brass Kemmerers. Water samples for metal analyses were collected with PVC Van Dohrns. All water and sediment samples were chilled until analyses could be conducted.

ANALYTICAL METHODS

Sediment. Particle size determinations and settleability tests were conducted by Aqua-Tech, Inc., Port Washington, Wisconsin. Particle size analyses were conducted by the use of standard mesh screens and a hydrometer for the fines (USDA system). The settleability test consisted of agitating a 20 percent sediment and river water mixture for 10 minutes, and taking turbidity and suspended solids readings at geometrically-increasing time intervals until 30 mg/l suspended solids or 7 days were reached.

Chemical analyses of the sediment samples were conducted by the U.S. Geological Survey Laboratory in Atlanta, Georgia. The chemical analyses were conducted according to EPA approved methods.

Microbiological analysis of the sediments was conducted by Dr. Jay Grimes of the University of Wisconsin, LaCrosse, Wisconsin. (Appendix H)

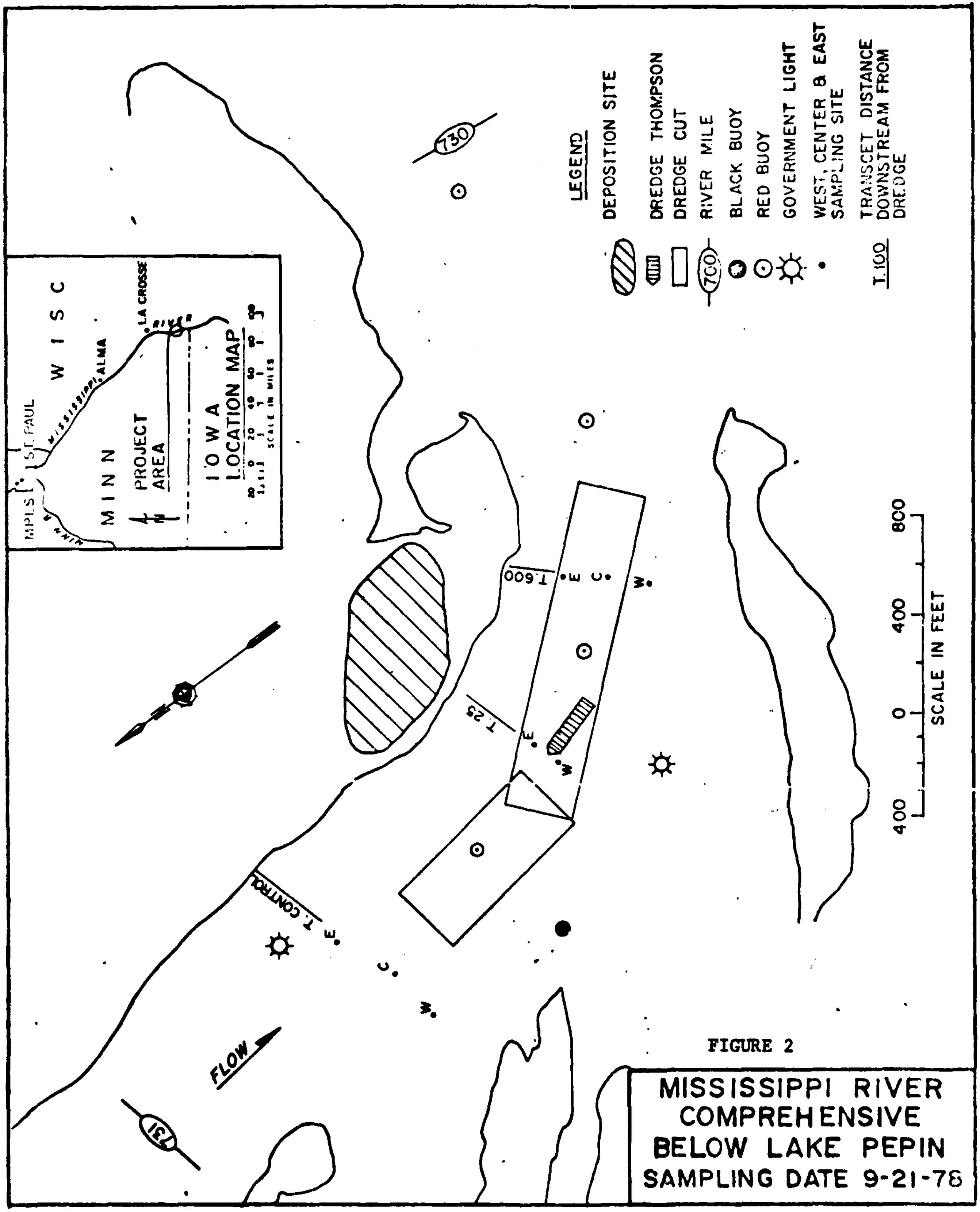


FIGURE 2

MISSISSIPPI RIVER
COMPREHENSIVE
BELOW LAKE PEPIN
SAMPLING DATE 9-21-78

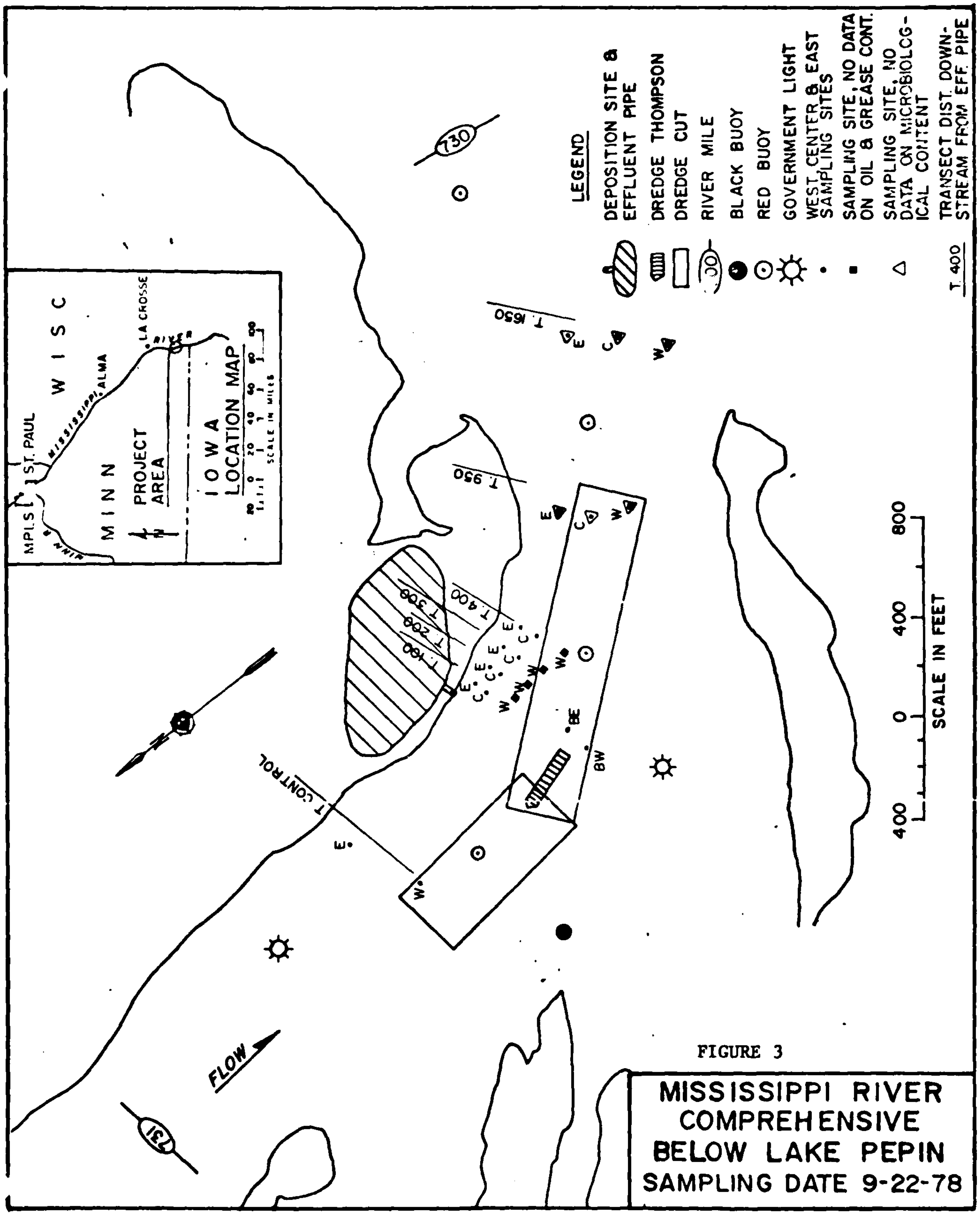


FIGURE 3

MISSISSIPPI RIVER
COMPREHENSIVE
BELOW LAKE PEPIN
SAMPLING DATE 9-22-78

RESULTS

FIELD CONDITIONS

Many delays were imposed on the sampling program (particularly the second phase) because of high barge traffic. Weather conditions were not adverse, with typically cool temperatures over the 3 days of sampling (50°F) and only a slight wind out of the northeast.

Current velocities were recorded for only 1 day of sampling (21 September 1978). Current velocities were fairly high, with a mean of 2.77 feet/second 1 foot below the surface and 2.47 feet/second 1 foot above the bottom.

SEDIMENT

Particle Size. Particle size analysis indicated that the sediments from the dredge cut consisted primarily of coarse to medium-sized sand particles, with those two particle sizes contributing over 90 percent of the total particle size distribution (Table 1). Fine material (clay and silt) was only found in trace amounts (less than 2 percent).

TABLE 1 - Percent composition of particle size distribution of sediments from the Wild's Bend dredge cut (River Mile 730.6) (Refer to Figure 1)

Classification \ Site	2 east	2 west	4 east	4 west
> Sand	4.51	7.96	8.04	2.68
Coarse Sand	65.26	70.69	68.88	61.42
Medium Sand	26.95	19.88	20.87	34.66
Fine Sand	0.10	0.07	0.03	0.04
Silt	1.79	0.00	0.99	0.00
Clay	1.39	1.34	1.19	1.19

The particle size data was comparable to other sediment studies done for this reach of the Mississippi River (GREAT I WQWG, 1978).

Settleability Tests. A settleability test was conducted on one of the sediment samples from the dredge cut (2 west, Figure 1). Measurements of turbidity and suspended solids immediately after shaking the sediment-water mixture indicated that the majority of the bottom material did not remain in suspension but settled out rapidly (Table 2). Within 35 minutes both turbidity and suspended solids values had dropped below Minnesota PCA effluent standards of 25 NTU and 30 mg/l, respectively. The initial concentrations and the time of settling of suspended material were generally comparable to a majority of other sites studied below Locks and Dam No. 2 on the Upper Mississippi River (see Appendix Tables 22 and 23).

TABLE 2 - Settleability of dredge site sediments as measured by turbidity and suspended solids at the Wild's Bend dredge cut

Time Interval (minutes)	Suspended Solids (mg/l)	Turbidity (NTU)
0	330	33
5	45	29
10	38	26
35	6	13
75	0.6	12
155	0.4	11

Bulk Chemical Constituents. Bulk chemical analyses of dredge site sediments revealed that dredge cut sediments were fairly non-polluted. Most of the metals and all of the pesticides and PCB's analyzed were below their respective detection limits (see Appendix Table F-1). Barium, iron, and manganese were the only metals found in any appreciable amounts; however, they were well within the range of values found below Pool 2 in the 1978 bottom sediment survey. Nutrient concentrations were also low, with mean concentrations for total Kjeldahl nitrogen of 185 mg/kg and total phosphorous of 99 mg/kg. Ammonia nitrogen was only slightly above the detection limits in two of the eight sediment samples. Analysis of sediment samples for residue lost on ignition (RE LOI) indicated that the dredge cut sediments contained an average of 4.4 percent volatile solids.

Microbiology. Indicator counts (fecal coliform, total coliform, and fecal streptococcus) in the dredge cut sediments were very low, and no salmonellae or shigellae isolations were made (Appendix H). Fecal coliform/fecal streptococcus ratios were generally indicative of mixed human and animal pollution of the sediments. See Dr. Jay Grimes' contract report for further discussion (Appendix H).

WATER

The water quality data collected over the 3 days of sampling are presented in Appendix Table E2. Pesticides and other chlorinated hydrocarbons were not included in this appendix because in all water samples concentrations of chlordane, polychlorinated naphthalene (PCN), and polychlorinated biphenys (PCB) were reported by the U.S. Geological Survey laboratory to be 0.0 ug/l; and aldrin, DDD, DDE, DDT, endosulfan, heptachlor epoxide, heptachlor, lindane, mirex, and perthane were reported to be 0.0 ug/l. In addition, soluble forms of selected parameters were measured in samples collected from six sites over the 3 days of sampling (Appendix Table E3).

Cadmium and lead had untypically high values in all water samples (Appendix Table E2). In addition, Appendix Table E3 indicates that soluble forms make up almost all of the total concentrations for those two metals. The U.S. Geological Survey Laboratory has indicated that contamination of water samples by cadmium and lead may have occurred because of paint on the nitric acid ampules which were used for the preservation of water samples for metals. For these reasons, the extremely high values for cadmium and lead were presumed to be the result of contamination and were not considered for further analysis in this report.

Physical Parameters. The data for the physical parameters were statistically tested with a student's t-test comparing mean control levels to mean plume levels for the hydraulic cutterhead and the disposal pipe (Table 3).

TABLE 3 Comparison of means for the physical parameters analyzed in background, control, and downstream (of the hydraulic cutterhead and disposal pipe) samples at the Wild's Bend dredge cut

Location	Date	Physical Parameters (Mean Concentrations)1					
		Residue Susp. 2	Residue Susp. 3	Residue Diss. 2	Residue Total 2	Turbidity (NTU) 2	Turbidity (NTU) 3
Background	9-19-78	25	31	163	199	11	8.8
Control	9-21-78	26	25	171	201	8.5	8.3
Cutter-Top	9-21-78	25	23	165	196	8.0	7.8
Cutter-Bottom	9-21-78	25	22	167	194	9.0	8.9
Control-Top	9-22-78	24.5	22.8	169	195	8	8.4
Control-Bottom	9-22-78	23.5	20.8	169	196	8	8.7
Disposal Top	9-22-78	22.3*	22.8	169.8	197	8	8.3
Disposal Bottom	9-22-78	21.2*	27.2*	171	198	8.2	8.8

1 All values are expressed in mg/l unless otherwise stated.

2 U.S.G.S. Results.

3 Contractor's results.

* Significant at $\alpha = .05$ from student's t-test comparing mean control values to mean plume values.

No significant differences were found between the means of upstream control samples and samples from downstream of the hydraulic cutterhead for suspended, dissolved, and total residues; and for turbidity. For the disposal site samples, the only statistically significant difference from the controls was for suspended solids. U.S. Geological Survey data indicated that there was a significant decrease in suspended solids from the disposal site, when compared to the control sites, both for the near-surface and near-bottom samples. However, data from the Contractor's report indicated no significant change near the surface and a significant elevation near the bottom at the disposal site. This contradiction between the two laboratories makes it difficult to draw any conclusions about suspended solids. However, it should be noted that very close agreement was found between the two laboratories for the near-surface samples, showing a mean difference in suspended solids of only 0.2 mg/l. Turbidity data also corresponded well between the two laboratories, having a mean difference of 0.36 NTU's.

Lateral positions on a transect below the disposal pipe had no effect on any of the physical parameters. Similar values were found at the east position, located closest to the disposal island, and at the center or west position, located further from the disposal island (Figure 3).

Water samples taken directly from the disposal pipe were found to be above background and control levels for total residue, suspended residue, and turbidity. Dissolved residue was not found above background or control levels in samples from the disposal pipe (Table 3). The turbidity and suspended solids values from the disposal pipe were similar to those recorded after only 5 minutes of settling time in the settleability test (Table 2). This would indicate that some settling did occur but was minor.

Background samples collected 2 days prior to dredging at the Wild's Bend dredge site had turbidity and suspended solids mean concentrations greater than those recorded in either controls or plumes for either day of monitoring of the dredging and disposal operations. This would indicate that natural daily fluctuations may be fairly large and may mask any physical impacts on water quality caused by a dredging operation at this site.

Nutrients. Samples collected directly from the disposal pipe had higher values for all the nutrients, except nitrate and nitrite, than background or control samples (Appendix Table E2). However, no statistically significant differences were found when comparing disposal site means with control site means for any of the nutrients. In fact, mean concentrations of the various nutrients from samples near the disposal site were lower than mean control concentrations. In addition, no significant differences were found between mean control values and near the cutterhead values (Table 4).

TABLE 4 Comparison of mean nutrient concentrations in background, control, and downstream (of the hydraulic cutterhead and disposal pipe) samples at the Wild's Bend dredge cut

Location	Date	Nutrients (mean concentrations)[1*]						
		NH_4 Nitrogen	Tot Nitrogen	NO_3 Nitrogen	Tot Organic Nitrogen	Kjeldahl Nitrogen	NO_2 & NO_3	Tot Ortho Phosphorous
Background	9-19-78	0.02	1.2	5.7	0.74	0.76	0.47	0.11
Control	9-21-78	0.01	1.3	5.7	0.73	0.75	0.54	0.13
Cutter-Top	9-21-78	0.02	1.3	5.7	0.74	0.74	0.54	0.12
Cutter-Bott	9-21-78	0.02	1.3	5.9	0.78	0.80	0.53	0.12
Control-Top	9-22-78	0.02	1.5	6.4	0.88	0.90	0.55	0.13
Control-Bott	9-22-78	0.02	1.5	6.6	0.92	0.93	0.55	0.13
Disposal-Top	9-22-78	0.013	1.4	6.3	0.84	0.85	0.57	0.12
Disposal-Bott	9-22-78	0.02	1.4	6.3	0.84	0.85	0.57	0.12

[1] All values are expressed in mg/l
*Significant at = .05 from a student's t-test comparing mean control values to mean plume values

Comparing the lateral sampling site position on a transect below the disposal pipe indicated that the east position located closest to the disposal island had higher levels of ammonia, Kjeldahl nitrogen, and total organic nitrogen than did the west or center position which were located further from the disposal island (Appendix Table E2). This seems to indicate that the disposal did have some minor effects on nutrient concentrations but that these were limited mainly to water immediately adjacent to the disposal island.

Background samples had a slightly lower concentration for most of the nutrients than control samples taken during the monitoring study. This would indicate that there are daily fluctuations in nutrient concentrations in this area.

Comparing dissolved Kjeldahl nitrogen and ortho-phosphorous with total concentrations for a few selected sites indicates that for both the control and plume samples a majority of the two nutrients were in the dissolved form, whereas the samples taken directly from the disposal pipe had a greater percentage in the suspended form.

Metals. Samples taken directly from the disposal pipe showed that manganese and iron were the only metals showing a substantial elevation over control and background samples, with mean concentrations of 5450 ug/l for iron and 2250 ug/l for manganese (Appendix Table E2). The metals data were statistically analyzed with student's t-test comparing the means of downstream of the disposal pipe samples and cutterhead samples to respective control means (Table 5). Iron and manganese were the only metals that showed a significant elevation above controls in the disposal pipe plume. Iron and manganese values were also elevated downstream of the cutterhead in comparison on the control values, but this elevation was found to be not significant with the student's t-test (a $+\alpha$ = .05).

TABLE 5 Comparison of mean metal concentrations in background, control, and downstream (of hydraulic cutterhead and disposal pipe) samples at the Wild's Bend dredge cut

Location	Date	Metals (mean concentrations)[1*]								
		Arsenic	Chromium	Copper	Cyanide	Iron	Manganese	Mercury	Nickel	Zinc
Background	9-19-78	2	3/10	3.6	0.0	960	127	< 0.5	15	38
Control	9-21-78	2	2/6	4	0.0	870	130	< 0.5	7	20
Cutter-Top	9-21-78	2	3/5	3	0.0	920	138	< 0.5	9.2	26
Cutter-Bott	9-21-78	2	2/5	4.6	0.0	930	134	< 0.5	11	26
Control-Top	9-22-78	2	0/4	3.8	0.0	830	132	< 0.5	14.3	25
Control-Bott	9-22-78	2	2/4	5.8	0.0	805	135	< 0.5	9.5	22
Disposal Top	9-22-78	1.6	6/24	3.2	0.0	895*	146*	< 0.5	8.5	18.2
Disposal Bott	9-22-78	2	6/24	3.5	0.0	889*	142*	< 0.5	7.9	18.2

[1]All values expressed as ug/l, with the exception of chromium, which is expressed in a ratio of the number of samples with detectable limits to total number of samples.

*Significant at = .05 from student's t-test comparing mean control values to mean plume values.

A comparison of variation with lateral position on a transect line for various sampling sites below the disposal pipe showed that manganese and iron elevations were found primarily at the east positions, the positions closest to the disposal island (Appendix Table E2). This finding would indicate that the impacts did not extend far out into the main channel but were mainly confined to the area immediately adjacent to the disposal island. Manganese dropped to control levels beyond 300 feet downstream of the disposal pipe, but iron readings were less tractable.

Total iron, nickel, and zinc concentrations were found to be substantially greater in background water samples than in control or plume samples. Daily fluctuations in concentrations for these parameters were greater than differences seen between control and plume values.

Comparing dissolved versus total concentrations of metals at selected sampling sites showed that dissolved concentrations for all the metals were fairly uniform among background, control, and plume values (Appendix Table A3). In all the samples analyzed for total and dissolved metals, the suspended concentrations of all the metals were much greater than the dissolved concentrations. As pointed out earlier, iron and manganese showed substantially greater total concentrations in the samples taken directly from the disposal pipe than from either the control or background samples. However, dissolved iron and manganese concentrations were generally similar in control, background, and disposal pipe samples. This indicates that very little release of iron and manganese occurred and that most of the iron and manganese was held in suspended form.

Miscellaneous. Dissolved chloride, total organic carbon, and chemical oxygen demand did not show much variation between the 3 days of sampling and control and plume values. Statistical analysis with student's t-test revealed no significant differences between control and plume values for any of the three parameters (Table 6).

TABLE 6 Comparison of means of the miscellaneous parameters analyzed in background, control, and downstream (of the hydraulic cutterhead and disposal pipe) samples

Location	Date	Miscellaneous (mean concentrations)[1*] Dissolved Chloride	Total Organic Carbon	Chemical Oxygen Demand	Oil and Grease	Phenols
Background	9-19-78	8.0	13	40	0.0	---
Control	9-21-78	8.4	11	44	one sample	0.7
Cutter-Top	9-21-78	8.1	11	42	0.0	0
Cutter-Bott	9-21-78	8.1	11	40	0.0	0.2
Control-Top	9-22-78	8.1	11.5	42.5	0.0	0.3
Control-Bott	9-22-78	8.2	11.8	44.7	0.0	1.5
Disposal Top	9-22-78	8.3	11.9	43.8	0.0	0.6
Disposal Bott	9-22-78	8.2	11.9	43.8	0.0	0.8

[1] All values are expressed in mg/l

*Significant at $\alpha = .05$ from student's t-test comparing mean control values to plume values.

Oil and grease were found in detectable levels in only one sample, a control sample taken 21 September 1978. Phenols were found at detectable levels in only a few samples (both control and plume samples).

Microbiological. Microbiological indicator densities were evaluated and statistically analyzed by Dr. Jay Grimes (see Appendix H for his report). Fecal coliform counts were generally greater than 400 per 100 millileters in background, control, and plume samples (Appendix H). Salmonellae, but no shigellae, were isolated from 10 of the total number of samples collected during the study (55), with 33 total isolates representing two serogroups. Upstream control samples on 22 September 1978 and background samples on 19 September 1978 accounted for 25 of the 33 total isolates.

One-way analysis of variance revealed no significant differences of fecal coliforms and total coliform densities among background and upstream controls collected on 21 September and on 22 September. However, a highly significant difference was evident in fecal streptococcus densities, with the background

samples showing the highest densities and the control samples on 22 September the lowest.

One-way analysis of variance also revealed no significant differences between upstream (control) densities of any of the indicator bacteria and the downstream (below the hydraulic cutterhead) densities on 21 September. In addition, no significant differences were found among upstream (control), near the cutterhead, and below the disposal pipe densities on 22 September.

COMPARISON OF RESULTS TO STATE EFFLUENT AND WATER QUALITY STANDARDS

Although the disposal site was located in Wisconsin, Minnesota State water quality and effluent standards were used for the comparison because the Minnesota standards are more comprehensive and because the waters of both States were affected by the dredging operation.

A comparison of the results of the samples collected directly from the disposal pipe to Minnesota effluent standards shows that suspended solids exceeded the 30 mg/l standard in both samples, with a mean concentration of 47 mg/l (Appendix Table E2). The turbidity effluent standard of 25 NTU was exceeded in one of the samples (30 NTU) but was below the standard in the other sample (21 NTU).

Of the metals investigated in this study, iron, copper, and zinc were found in excess of the Minnesota Pollution Control Agency (MPCA) proposed water quality standards (iron: 1000, copper: 5, zinc: 38 ug/l; taken from MPCA Draft Water Quality Standards, 24 January 1979; a hardness of 160 mg/l was used for the determination). However, for all three of these metals, values exceeding standards were equally distributed among samples from background, control, and downstream of the cutterhead and disposal pipe. In fact, the highest percentage of samples exceeding standards out of the total samples for iron and zinc occurred on 19 September prior to dredging (60 percent).

Phenols exceeded the proposed MPCA standard of 1 ug/l in several samples, but they were equally distributed between control samples and those downstream of the cutterhead and disposal pipe. In almost every sample, fecal coliform densities exceeded the proposed standard.

Ammonia nitrogen was detected in the range of 0.00 to 0.07 mg/l. At these levels, and at the temperature and pH range normally found during this time of year in the area of the dredge site, un-ionized ammonia would not have been at levels exceeding the proposed MPCA standard of 0.02 mg/l.

SUMMARY OF FINDINGS

1. The sediments at the Wild's Bend dredge cut were coarse, mainly consisting of medium to coarse-sized sand particles, with only traces of silt and clay. The settleability tests supported the particle size data in that the tests indicated a low initial concentration of suspended solids with rapid settling. Bulk chemical and microbiological investigations of the sediments from the dredge cut found them to be relatively uncontaminated.

2. Physical impacts on water quality resulting from the hydraulic cutterhead and the effluent from the confined on-land disposal area were minimal. No significant elevations downstream of the dredge or disposal island were found. Normal daily fluctuations were much greater than any effect from the dredging operation.

3. No significant elevations in nutrient levels resulting from the hydraulic cutterhead or effluent from the confined on-land disposal area were found. However, there did appear to be a slight elevation of ammonia, Kjeldahl, and total organic nitrogen immediately adjacent to the disposal area.

4. Polychlorinated biphenyls and pesticides were not found above the detection limits in any of the background, upstream control, or downstream (of the hydraulic cutterhead and disposal pipe) water samples.

5. Of the metals studied, iron and manganese were the only ones that showed significant elevations downstream of the disposal pipe. Manganese returned to upstream control levels within 400 feet of the disposal pipe. However, for both iron and manganese, daily fluctuations were greater than those caused by either the hydraulic cutterhead or the effluent from the confined on-land disposal area. It should also be noted that iron and manganese are two of the metals least toxic to aquatic life.

6. Microbiological indicator densities were generally high in all water samples, with fecal coliform densities usually greater than 400 per 100 milliliters. However, dredging or disposal of the dredged material did not significantly increase the densities of the indicator bacteria.

7. Dissolved chloride, total organic carbon, chemical oxygen demand, oil and grease, and phenols did not show any significant elevations over upstream control samples in water samples taken downstream of the hydraulic cutterhead and disposal pipe.

8. Turbidity and suspended solids in the disposal pipe samples slightly exceeded MPCA's effluent standards for these parameters.

9. Iron, copper, zinc, phenols, and fecal coliforms were found in at least some samples exceeding the proposed MPCA water quality standards. However, values exceeding the standards were found equally distributed among pre-dredging samples (background), upstream control samples, and samples downstream of the hydraulic cutterhead and disposal pipe.

10. Turbidity and suspended solids values at 5 minutes settling time in the settleability tests were generally comparable to values in the effluent from the disposal area, indicating that some settling occurred in the disposal area but was minor.

11. Daily fluctuations in concentrations of most parameters were evident and tended to mask any effect on water quality resulting from the dredging and disposal operations.

CONCLUSIONS

The 20-inch hydraulic dredge, WILLIAM A. THOMPSON, dredged at Wild's Bend (River Mile 730.5) from 21 September through 25 September 1978. Disposal of the dredged material occurred in a confined on-land disposal area, with a drop structure to allow a return of water after a short retention time. Microbiological, chemical, and physical effects on water quality resulting from the hydraulic cutterhead and the effluent from the confined on-land disposal were monitored.

The hydraulic cutterhead did not cause any statistically significant elevations in concentrations downstream at the cutterhead for any of the parameters investigated in this study. This is probably attributable to the dredging of relatively coarse, clean sediments.

The effluent from the confined on-land disposal area contained concentrations of some of the parameters (especially for iron, manganese, and the physical parameters) exceeding the pre-dredging and upstream control values. However, iron and manganese were the only ones found to be significantly higher downstream of the disposal pipe than upstream control values. Because iron and manganese are ubiquitous on the Upper Mississippi River, they will probably show some reaction in most dredging operations. Elevations in concentrations of some nutrients were found. However, they were limited to the area immediately adjacent to the disposal area, indicating that very rapid settling and dilution occurred at the disposal site.

Some of the parameters analyzed during the study had values exceeding MPCA's proposed water quality standards. However, it cannot be concluded that they were a result of the dredging or disposal operation, because they were equally distributed among pre-dredging samples (background), upstream control samples, and samples downstream of the hydraulic cutterhead and disposal pipe.

No major degradation of water quality resulting from the operation of a 20-inch hydraulic dredge and the subsequent disposal of dredged material in a confined on-land disposal area with a discharge pipe was evidenced in this study. In fact, daily fluctuations for most of the parameters were greater than elevations in concentrations resulting from the dredging and disposal operations.

READ'S LANDING (RIVER MILE 763) - MONITORING OF TURBIDITY AND SUSPENDED SOLIDS CHANGES FROM HYDRAULIC DREDGING

OBJECTIVE

The objective of this study was to monitor turbidity and suspended solids changes in water quality resulting from a hydraulic dredging operation at Read's Landing on the Upper Mississippi River.

METHODS

DESCRIPTION OF SAMPLING SITES

The Read's Landing dredge cut on the Upper Mississippi River is located near the mouth of the Chippewa River, river mile 763. The Chippewa River carries large loads of coarse suspended material which settles quickly upon entering the slower moving Mississippi River. This situation makes Read's Landing one of the longest dredge sites on the Upper Mississipi River and one that requires frequent dredging, approximately 2 out of every 3 years. From 1956 to 1977, the volume of material dredged per job has ranged from 11,000 to 314,000 cubic yards, with an average of 115,400 cubic yards per job.

During the 1978 maintenance dredging season, this site was dredged twice with the WILLIAM A. THOMPSON, a hydraulic dredge. The second dredging started on 11 August 1978 and terminated on 17 August 1978. The THOMPSON dredged two cuts approximately 200 feet by 1,650 feet to a depth of 12 feet, removing 43,612 cubic yards of material. The disposal of the dredged material occurred on the Wisconsin side of the channel at approximately river mile 763.0 in a diked containment area. The original diked containment area covered approximately 24 acres with a functional capacity of about 150,000 cubic yards. However, previous placement of dredged material in this diked area had reduced the capacity by about 20 to 30 percent.

EXPERIMENTAL DESIGN

The sampling program consisted of 2 phases. In the first phase, water samples were collected on 14 August 1978 from sampling sites located on six transects. Five transects were located 50, 100, 200, 400, and 800 feet downstream of the dredging operation; and one transect, the control, was located 600 feet upstream of the dredge (refer to Figure 4). Each transect had three sampling sites (i.e., east, center, and west). At each site, samples were collected at two depths, 1 foot from the surface and 1 foot from the bottom. Samples were collected simultaneously from sites on a transect and at the two depths previously mentioned.

In the second phase, water samples were collected on 15 August 1978 from sites located on five transects. Four of the transects were located 50, 150, 350, and 750 feet downstream of the dredging operation; and one control transect was located 600 feet upstream of the dredge (refer to Figure 5). Each transect had four sampling sites designated east, east-center, west-center, and west. Samples were collected simultaneously from each of the four sites and at two depths, 1 foot from the surface

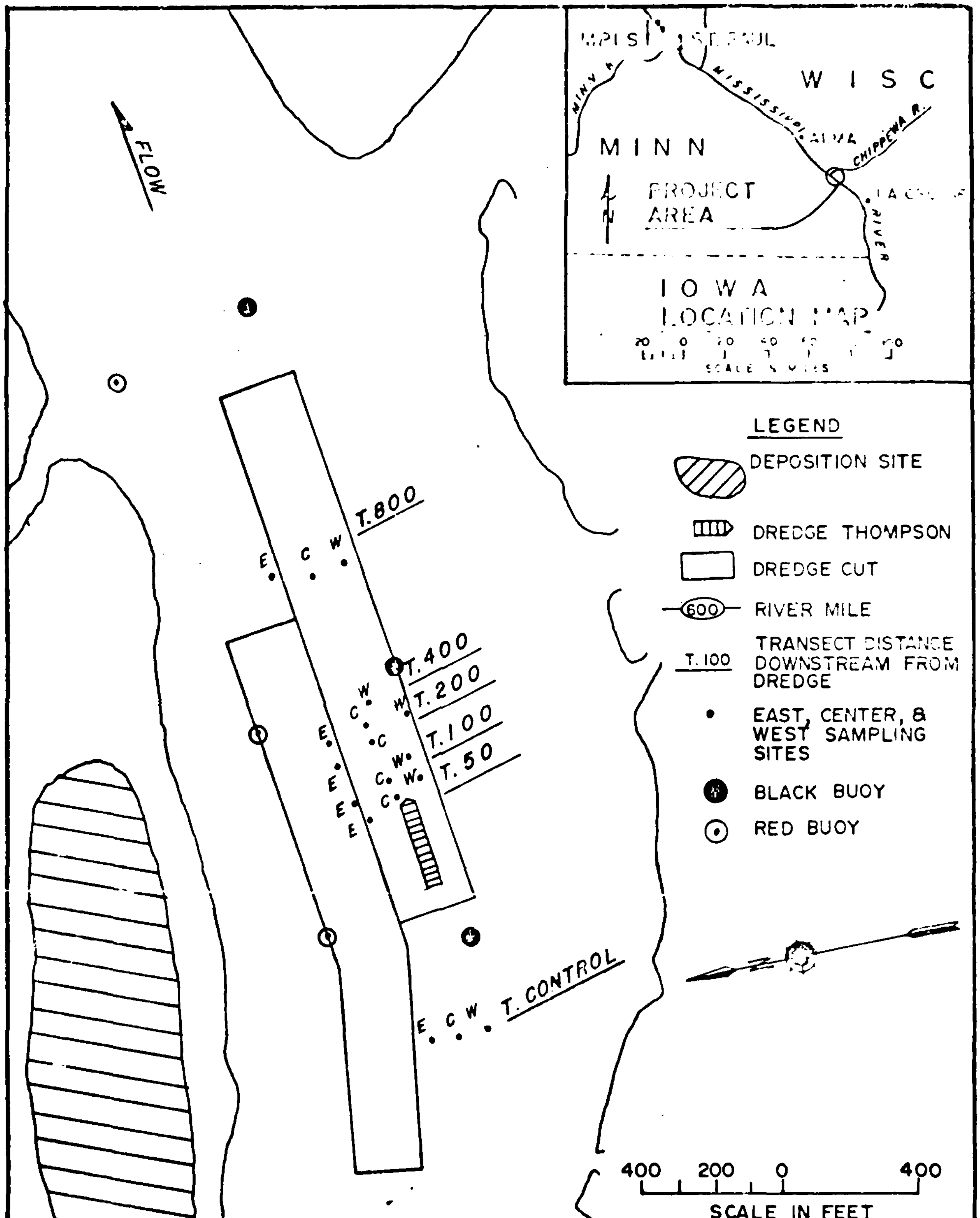


FIGURE 4

MISSISSIPPI RIVER
READ'S LANDING
PHASE I
SAMPLING DATE
8-14-78

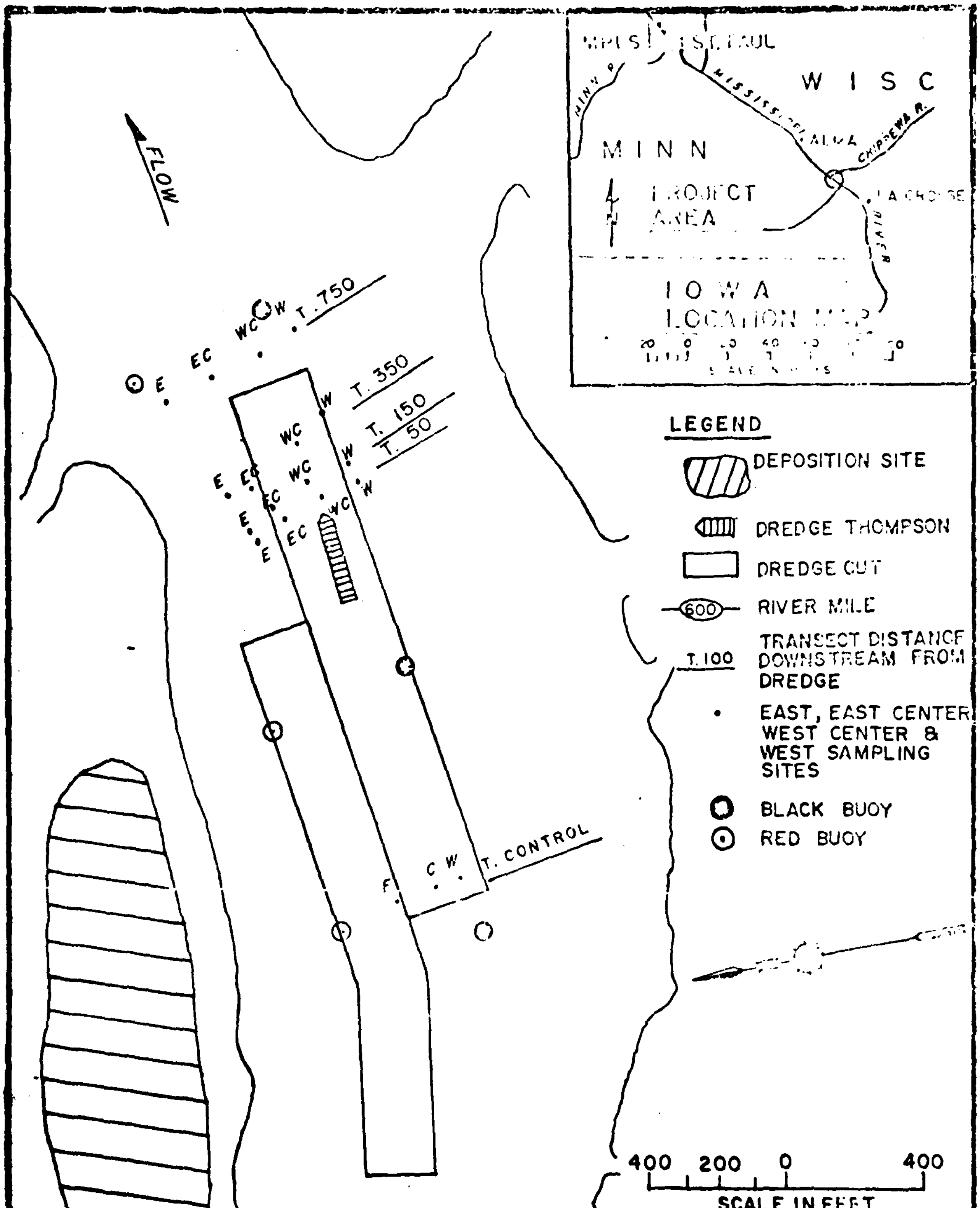


FIGURE 5

MISSISSIPPI RIVER
READ'S LANDING
PHASE II
SAMPLING DATE
8-15-78

and 1 foot from the bottom.

Following the collection of water samples, current velocity was measured by drogues. Measurements were taken twice at 200 feet downstream of the dredge and at two depths, at the surface and 3 feet from the bottom.

ANALYSIS METHODS

Samples were chilled after collection and shipped as soon as possible for laboratory analysis. Collection and analysis of turbidity and suspended solids followed guidelines set forth in "Methods For Chemical Analysis of Water and Wastes" (EPA, July 1974). Analyses were conducted by Aqua-Tech, Inc., Port Washington, Wisconsin.

RESULTS

FIELD CONDITIONS

Sample collection occurred at 1330 hours on 14 August and 1430 hours on 15 August 1978, under sunny skies, and lasted about 1 hour. Results of current measurements (taken twice at 200 feet downstream of the dredge) are shown in the following table:

TABLE 7

Current Measurements at Read's Landing* (8/15/78)

Location	Velocity
Surface	1.30 ft./sec.
Surface	0.97 ft./sec.
3 feet from bottom	0.85 ft./sec.
3 feet from bottom	0.82 ft./sec.

* It should be noted that the current velocities are general estimates since they were taken with drogues.

TURBIDITY AND SUSPENDED SOLIDS

Turbidity measurements in both phases of sampling were well below the Minnesota Pollution Control Agency established standard of 25 turbidity units (NTU). In phase I, turbidity measurements in near-surface and bottom samples did not show any significant variation. The turbidity values in surface samples were low, ranging from 6.0 to 7.0 NTU, while the values from bottom samples ranged from 6.2 to 7.2 NTU (Table 8). In phase II, turbidity values in both near-surface and bottom samples were also uniform and low. Turbidity measurements ranged from 5.7 to 7.8 NTU in near-surface samples, and 5.8 to 7.7 NTU in near-bottom samples (Table 9).

TABLE 8 Read's Landing Dredge Cut (8/14/78). Comparison of Turbidity and Suspended Solids at Two Depths With Distance Downstream of a Hydraulic Dredge. (Analysis Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin.) Phase I.

TABLE 8A Turbidity (NTU's)

		Surface			Bottom		
Transect		East	Center	West	East	Center	West
Distance from Dredge (feet)	Control	7.0	7.0	7.0	6.7	6.7	6.2
	50	6.3	6.3	6.2	7.2	6.5	6.3
	100	6.3	7.0	6.3	6.2	6.3	6.8
	200	6.2	6.5	6.7	6.8	6.8	6.8
	400	6.0	6.5	6.7	6.8	6.8	6.8
	800	6.8	6.8	6.2	7.0	7.0	7.2

TABLE 8B Suspended Solids (mg/l)

		Surface			Bottom		
Transect		East	Center	West	East	Center	West
Distance from Dredge (feet)	Control	13	8.0	13	11	3.3	11
	50	18	18	6.7	7.3	15	5.7
	100	7.3	7.0	16	14	4.3	15
	200	15	12	13	14	16	9.7
	400	14	11	13	15	17	17
	800	15	8.7	3.3	6.0	5.7	12

TABLE 9 Read's Landing Dredge Cut (8/15/78). Comparison of Turbidity and Suspended Solids at Two Depths with Distance Downstream of a Hydraulic Dredge. (Analysis Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin.) Phase II.

Table 9A Turbidity (NTU's)

Transect		Surface				Bottom			
		East	E. Center	W. Center	West	East	E. Center	W. Center	West
	Control	6.3	6.3	6.2	--	6.7	6.2	6.5	6.5
Distance from Dredge (feet)	50	6.0	6.2	6.5	7.8	6.8	6.7	7.2	7.3
	150	5.7	6.5	6.3	6.6	6.4	6.6	6.2	7.2
	350	6.7	6.8	6.2	7.5	7.4	6.7	6.3	6.6
	750	6.3	6.3	6.0	5.9	6.7	6.7	5.8	7.7

Table 9B Suspended Solids (mg/l)

Transect		Surface				Bottom			
		East	E. Center	W. Center	West	East	E. Center	W. Center	West
	Control	2.7	17	7.7	3.3	12	20	10	7.0
Distance from Dredge (feet)	50	8.3	19	16	12	5.0	15	4.7	1.5
	150	5.0	8.3	4.3	4.3	24	15	19	2.3
	350	3.0	4.3	16	9.3	7.3	6.7	17	7.3
	750	6.7	17	9.0	20	6.3	13	2.3	14

On 14 August 1978, suspended solids measurements in the first phase of sampling ranged from 3.3 to 18.0 mg/l in near-surface samples, and 3.3 to 17 mg/l in the near-bottom samples. The highest value (18 mg/l) in near-surface samples occurred at 50 feet from the dredge on the east and center sampling sites. In near-bottom samples, the maximum value (17 mg/l) was noted at 400 feet from the dredge on the west and center site locations (Table 8B).

In the second phase (15 August 1978), suspended solid measurements from surface and bottom samples ranged from 2.3 to 24 mg/l. The highest suspended solids value in near-surface samples (19 mg/l) occurred at 50 feet from the dredging operation on the east-center transect location. In bottom samples, the maximum (24 mg/l) value occurred at 150 feet from the dredge on the east site. Values ranged from 7 to 20 mg/l on the control transect located 600 feet upstream from the dredge (Table 9B).

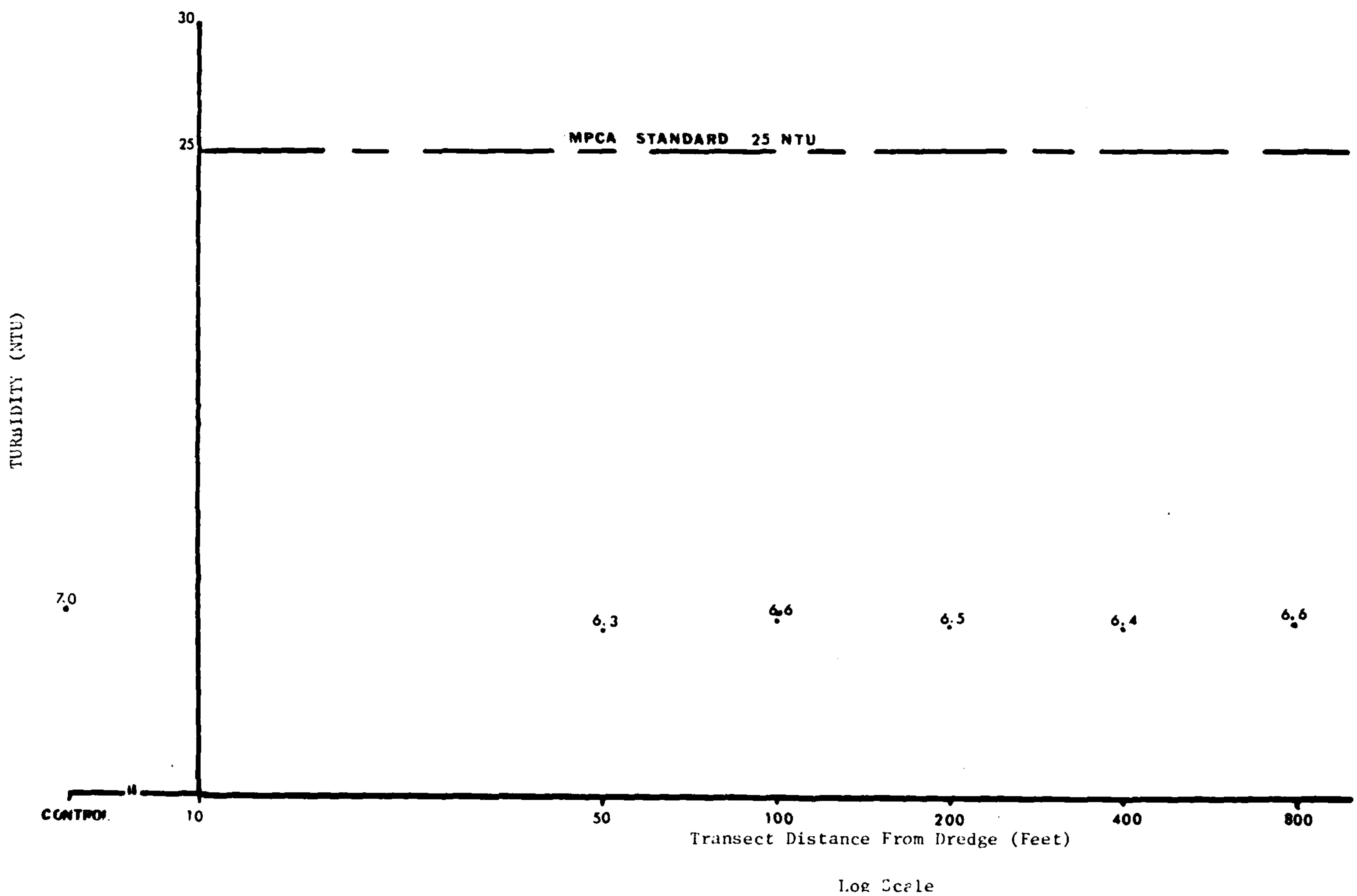
None of the suspended solids values in phase I or II exceeded the MPCA standard of 30 mg/l.

STATISTICAL EVALUATION

Phase I. Analysis of variance (ANOVA) for turbidity and suspended solids was conducted by Dr. Frank Martin of the University of Minnesota. In phase I, the main effects studied were transect distance (50, 100, 200, 400, and 800 feet downstream from the dredge; and the control, 600 feet upstream from the dredge) and site location (east, center, west) on the transect. Data from top and bottom samples were analyzed separately.

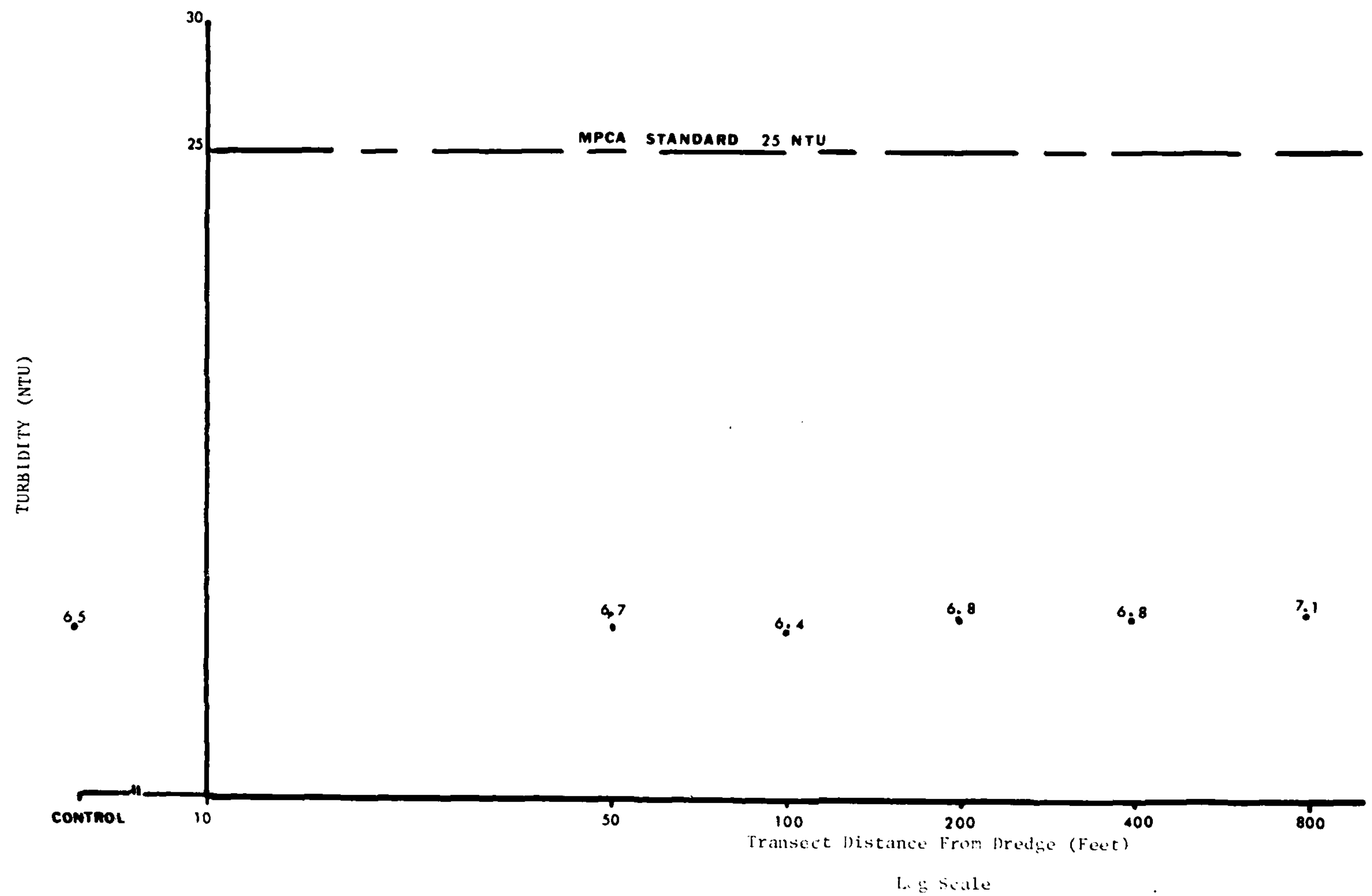
Statistical analysis of the data showed that turbidity and suspended solids levels from both near-surface and near-bottom samples in phase I were not significantly affected by transect distance from the dredge (Appendix Tables A1 through A4). Figures 6 and 7 show that mean turbidity values for transects upstream or downstream of the dredge did not fluctuate by more than 1 NTU. Although mean suspended solids values (Figures 8 and 9) for near-surface and near-bottom samples appear to decrease with distance from the dredge, this tendency is not statistically significant.

FIGURE 6 Mean* near-surface turbidity values (NTU) for transects downstream of dredge at Read's Landing, Phase I, 8-14-78



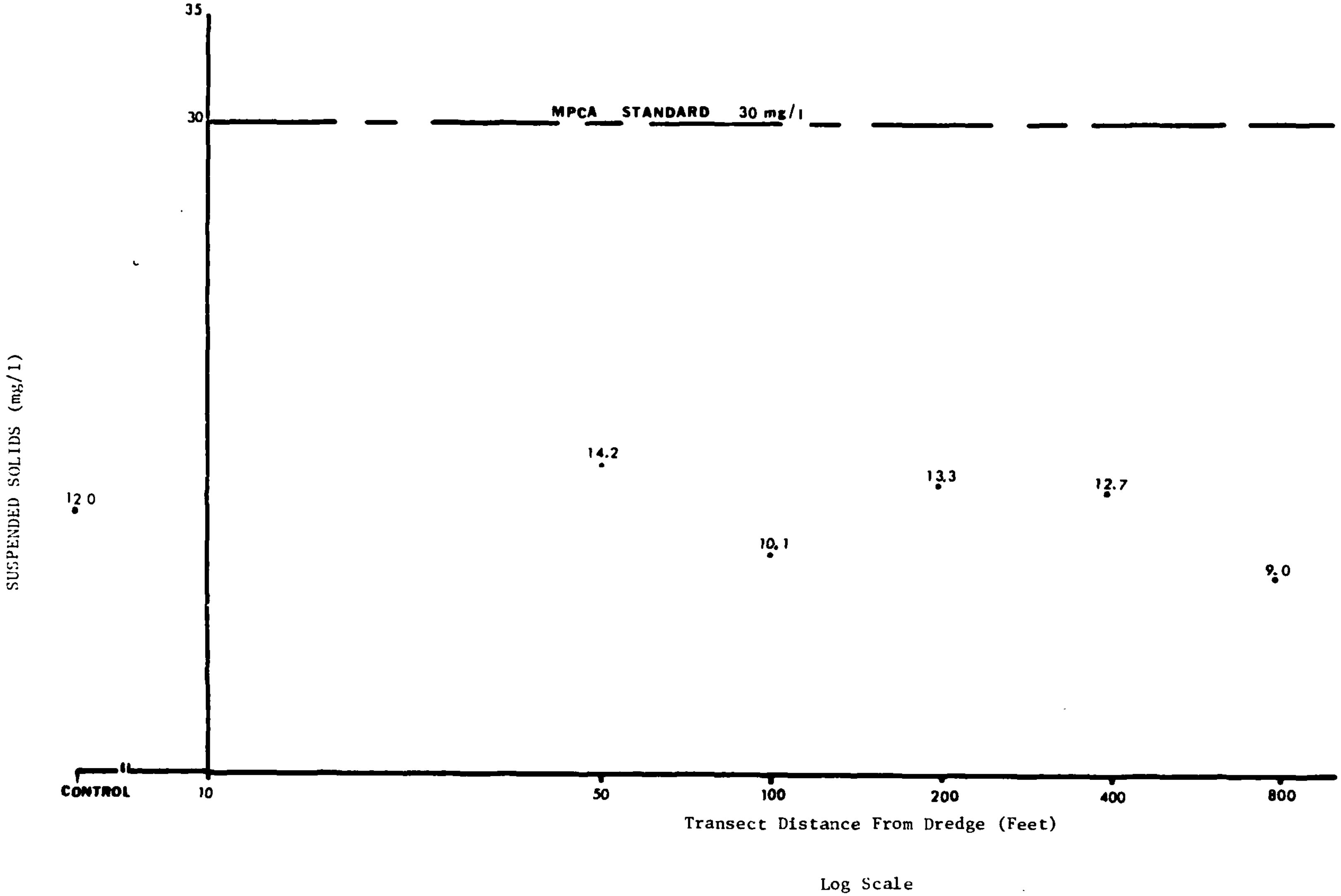
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 7 Mean* near-bottom turbidity values (NTU) for transects downstream of dredge at Read's Landing, Phase I, 8-14-78



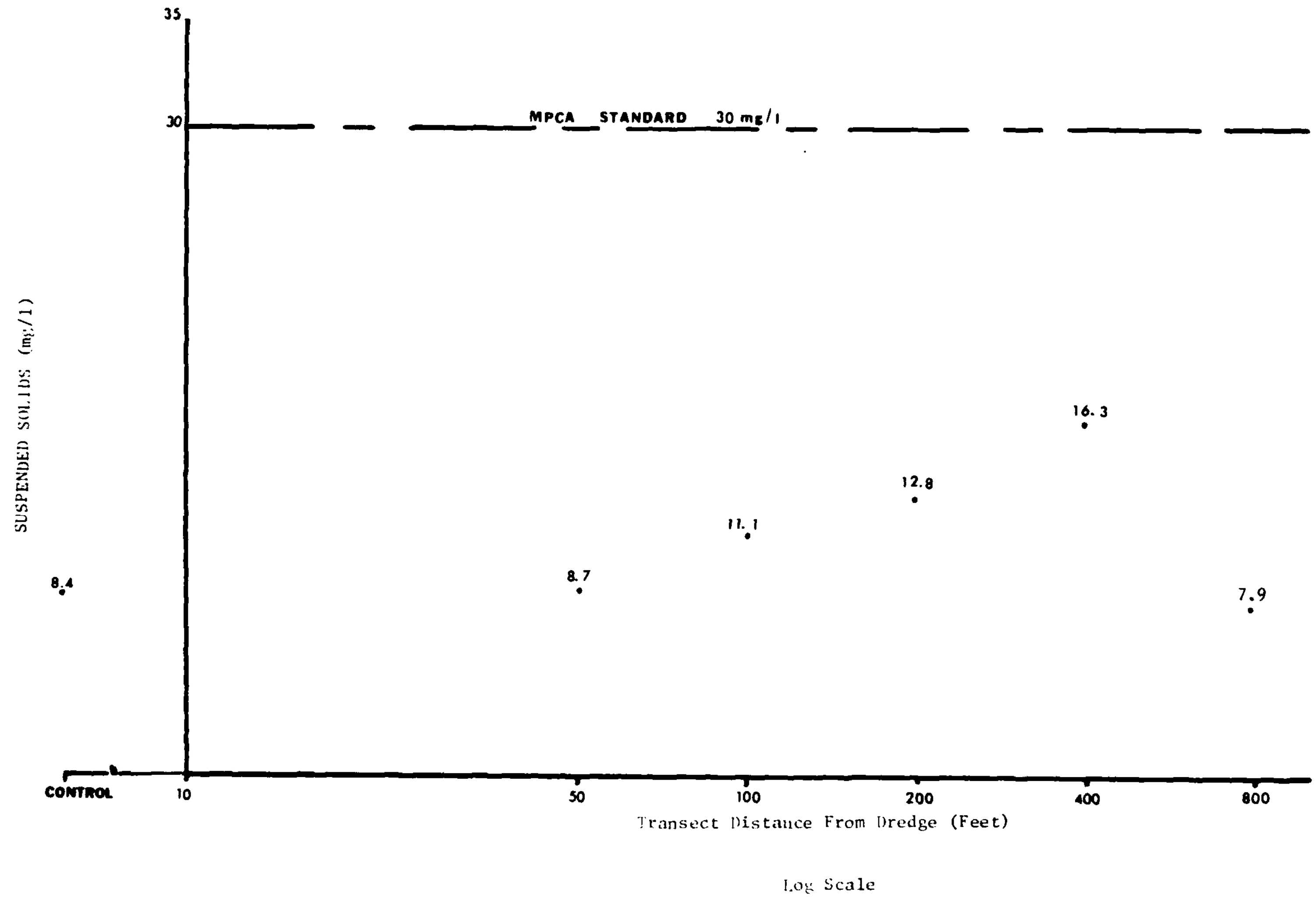
*Data represents arithmetic [illegible] collected [illegible]

FIGURE 8 Mean* near-surface suspended solids (mg/l) for transects downstream of dredge at Read's Landing, Phase I, 8-14-78



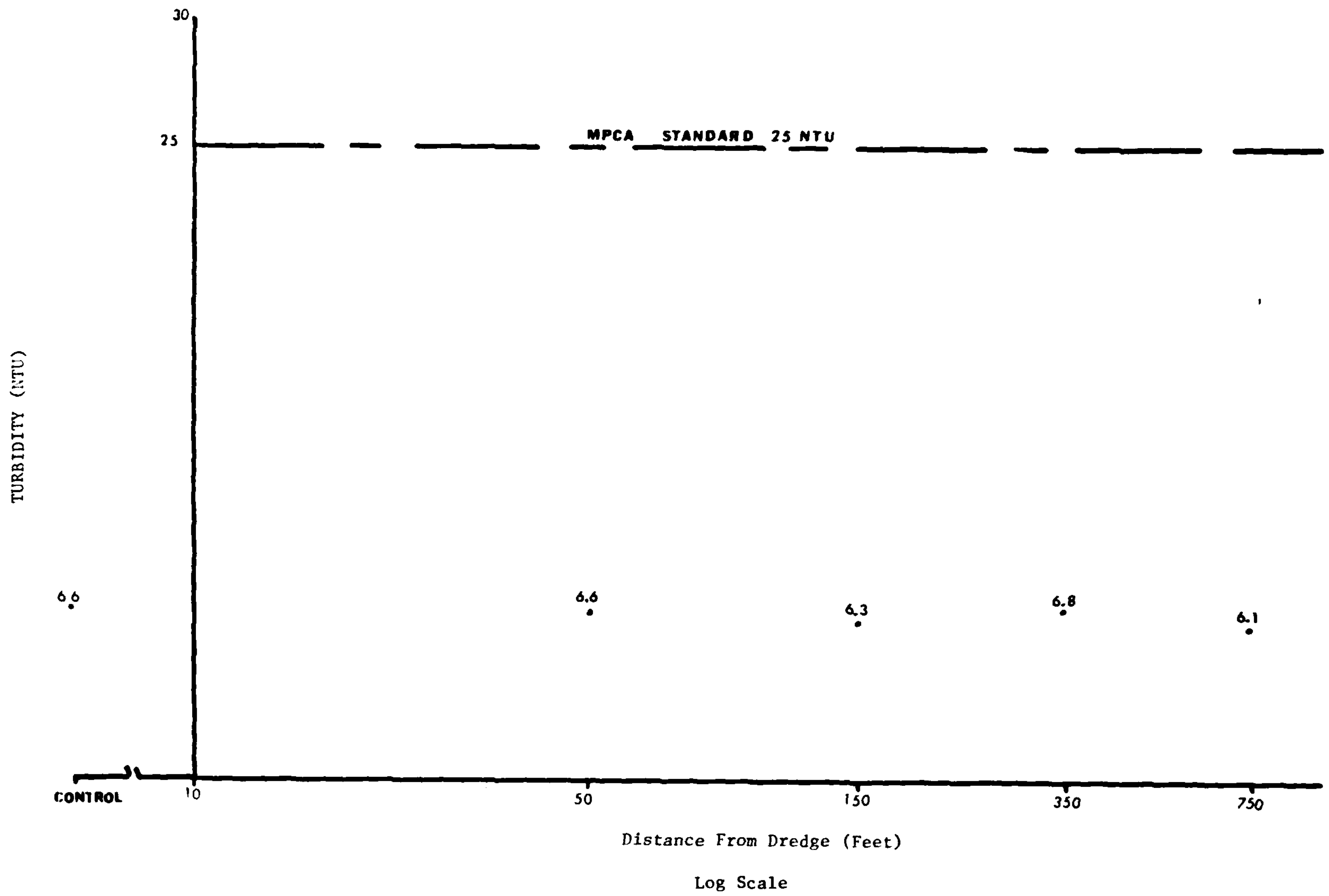
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 9 Mean* near-bottom suspended solids (mg/l) for transects downstream of dredge at Read's Landing, Phase I, 8-14-78



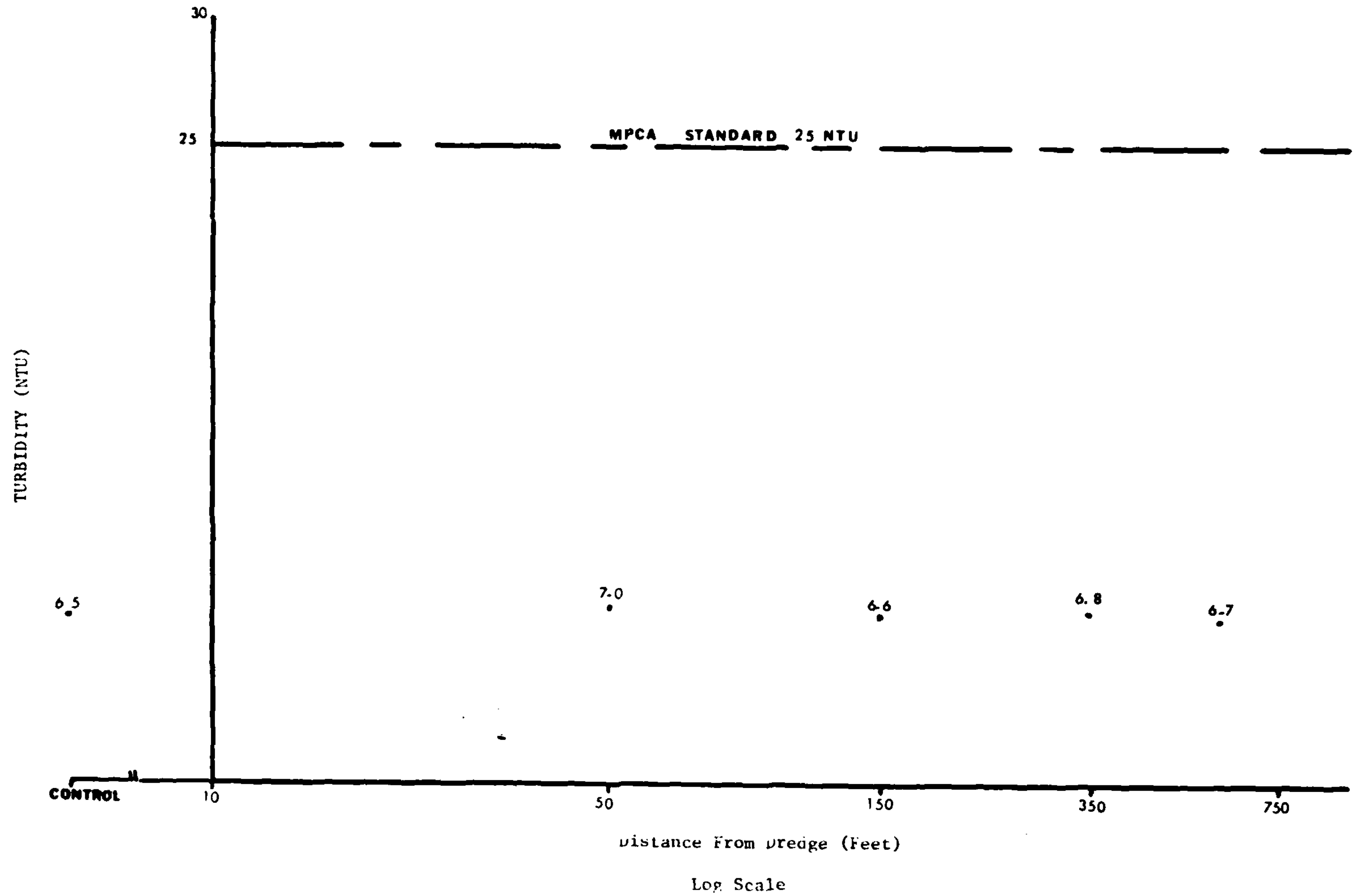
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 10 Mean* near-surface turbidity values (NTU) for transects downstream of dredge at Read's Landing, Phase II, 8-15-78



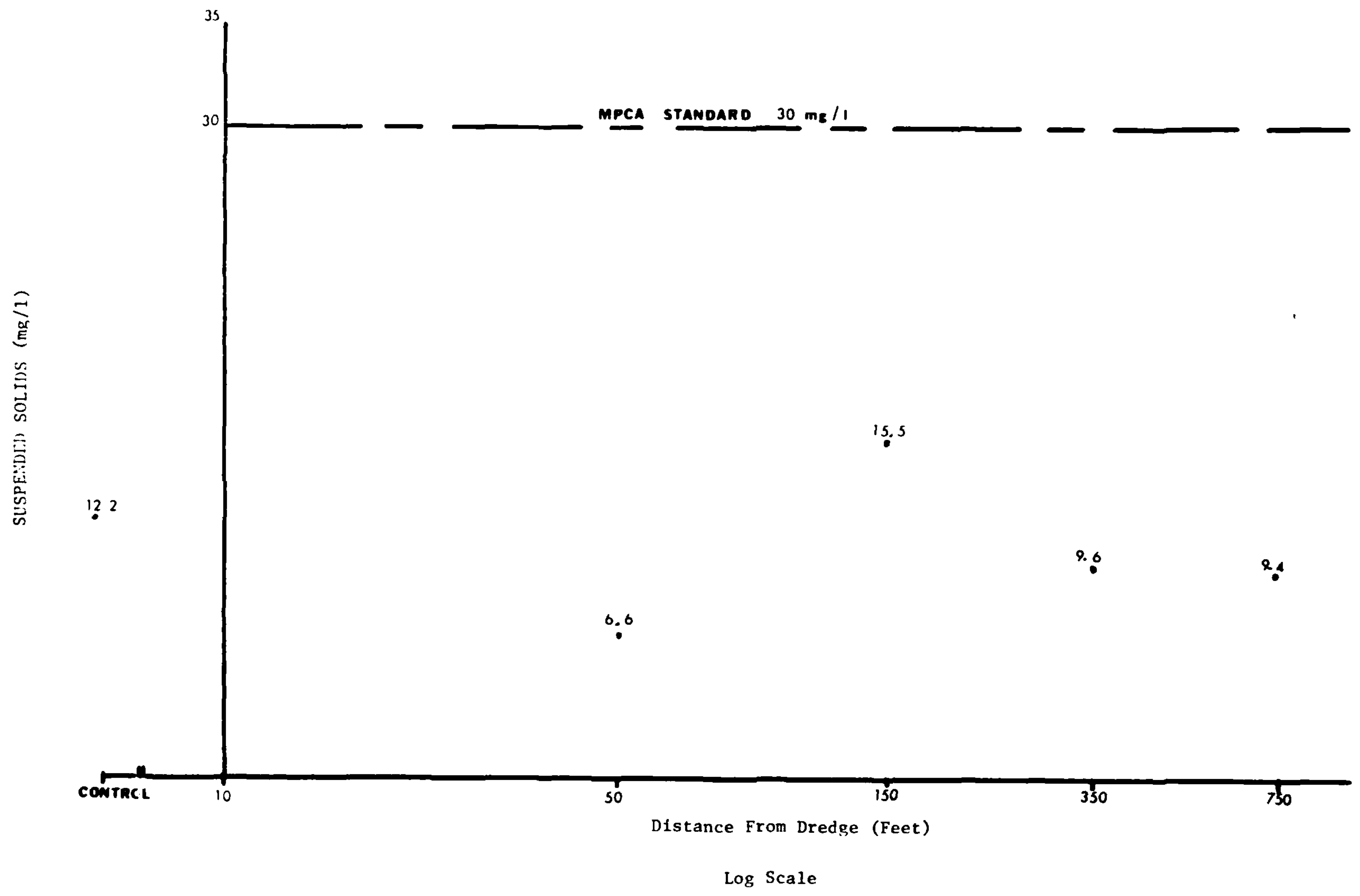
*Data represents arithmetic mean of water samples collected from four sites on each transect.

FIGURE 11 Mean* near-bottom turbidity values (NTU) for transects downstream of dredge at Read's Landing, Phase II, 8-15-78



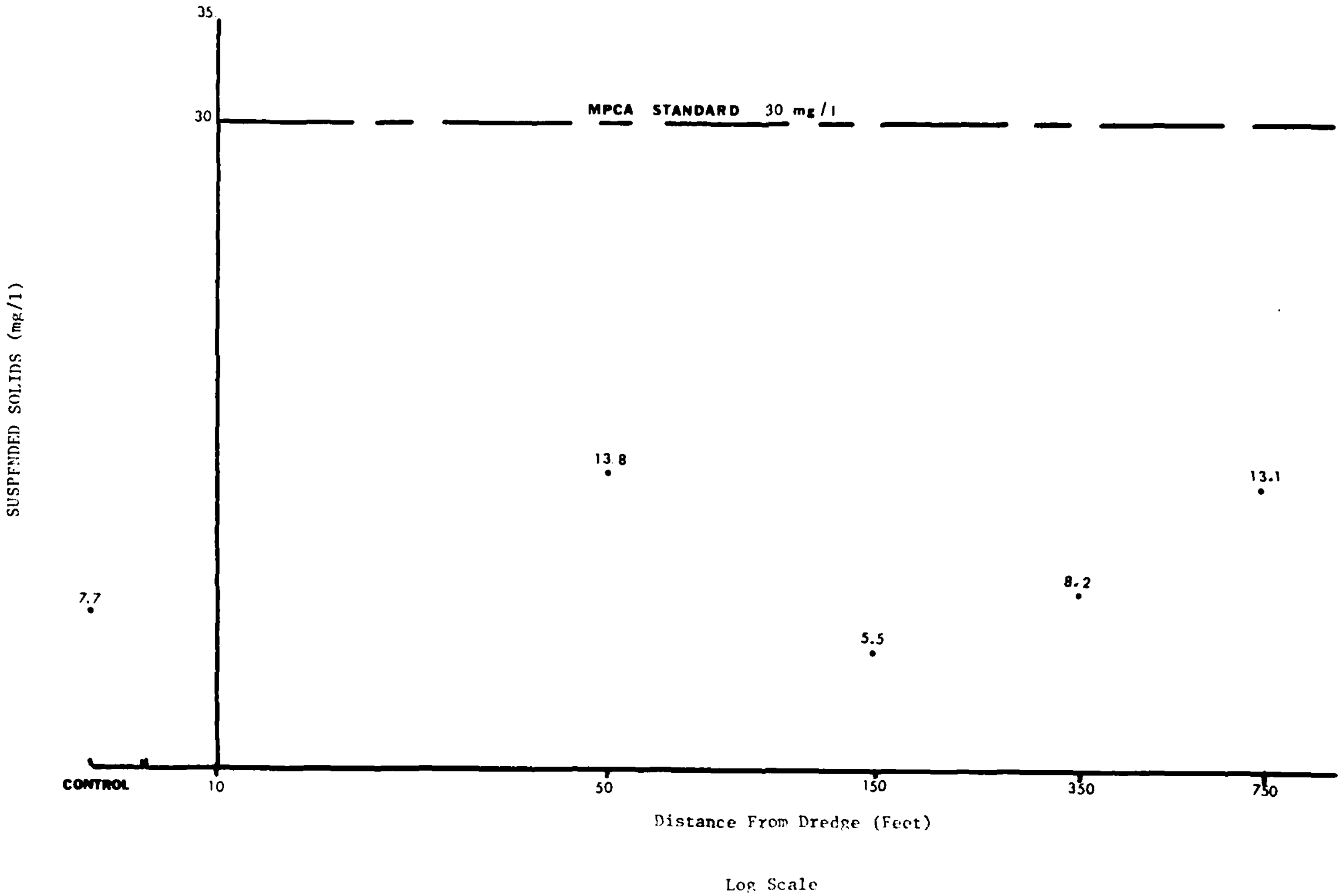
*Data represents arithmetic mean of water samples collected from four sites on each transect.

FIGURE 12 Mean* near-surface suspended solids values (mg/1) for transects downstream of dredge at Read's Landing, Phase II, 8-15-78



*Data represents arithmetic mean of water samples collected from four sites on each transect.

FIGURE 13 Mean* near-bottom suspended solids values (mg/l) for transects downstream of dredge at Read's Landing, Phase II, 8-15-78



*Data represents arithmetic mean of water samples collected from four sites on each transect.

Phase II. In phase II, the variables studied were transect distance (50, 150, 350, and 750 feet downstream; and the control 600 feet upstream) and site location (west, west-center, east-center, and east).

Statistical analysis of turbidity data from the near-surface samples showed that the distance of the transect from the dredge had no effect on turbidity (Appendix Table A5). A comparison of mean concentrations for each of the transects downstream from the dredge shows fluctuations of less than 1 NTU (Figure 10). However, statistical analysis of turbidity data revealed a significant variation in turbidity with sampling site location on the transects (Appendix Table A5). Compared to other sites, turbidity values from west sampling sites on all transects were higher by .4 NTU (Table 9A).

Turbidity concentrations from the near-bottom samples were not affected by transect distance or site location (Appendix Table A6; Figure 11).

Statistical analysis of suspended solids data for near-surface and near-bottom samples indicated no significant trend with distance downstream of the dredge (Appendix Table A7 and A8). Similarly, site location had no effect on the level of suspended solids in either near-bottom or near-surface samples (Appendix Table A7 and A8 and Figures 12 and 13).

SUMMARY OF FINDINGS

1. Turbidity values in water samples collected during dredging on 14 and 15 August 1978 in phases I and II, respectively, were uniformly low and well below MPCA's standard of 25 NTU.

2. Suspended solids values from samples collected during dredging were below MPCA standards of 30 mg/1.

3. Statistical analysis of phase I data showed that turbidity and suspended solids levels were not significantly affected by transect distance. In addition, turbidity and suspended solids levels were not significantly affected by lateral location of the sampling site on a transect, except turbidity near-surface values. The turbidity and suspended solids data did not show any trends with distance upstream or downstream of the dredge.

4. In phase II, turbidity levels in near-surface samples were significantly affected by lateral site location on the transect. Turbidity values were higher on west sampling sites than those on east, east-center, or west-center sites. This is probably attributable to hydrological features of the area, rather than anything associated with the dredging operation.

5. Turbidity levels in bottom samples were not affected by lateral sampling site location.

6. Suspended solids values in both near-surface and near-bottom samples were not significantly affected by transect distance from the dredging operation or lateral site location on a transect. The suspended solids data did not show any trends with distance from the dredge.

7. Mean turbidity values from transects located upstream and downstream of the dredge were very uniform, fluctuating within 1 NTU. Mean suspended solids were less uniform than turbidity, fluctuating within 5 mg/l.

8. Neither turbidity nor suspended solids fit any model of a decay curve comparing distance from the dredging operation.

9. The turbidity and suspended solids values from the 2 davs of sampling were comparable, indicating a relative uniformity in ambient water quality.

CONCLUSIONS

Turbidity and suspended solids levels were not significantly affected by the hydraulic cutterhead of the WILLIAM A. THOMPSON at Read's Landing on the Upper Mississippi River. Turbidity values from transects located upstream and downstream of the dredge were comparable and fluctuated within 1 NTU. Although suspended solids levels were less uniform, these values fluctuated within 5 mg/l. No trends in turbidity and suspended solids levels with transect distance from the dredge were noted. It would appear that the dredge was not acting as a point source for increased levels of turbidity or suspended solids. All values were below MPCA standards.

UPPER LANSING LIGHT (RIVER MILE 664) - MONITORING OF TURBIDITY AND SUSPENDED SOLIDS CHANGES RESULTING FROM HYDRAULIC DREDGING AND EFFLUENT FROM CONFINED ON-LAND DISPOSAL

OBJECTIVE

The objective of the study was to determine the areal extent of turbidity and suspended solids changes resulting from a WILLIAM A. THOMPSON hydraulic dredging operation and the effluent from confined on-land disposal of the dredged material.

METHODS

DESCRIPTION OF SAMPLING SITE

The Upper Lansing Light dredge cut area is located approximately 1 mile upstream of Lansing, Iowa, at river mile 664 of the Upper Mississippi River. The area is located along a large bend in the main navigational channel swinging from the Wisconsin to the Iowa shore. Because of this bend, shoaling occurs quite frequently in this area, requiring maintenance dredging approximately every other year. From 1956 to 1977, the volume of material dredged per job has ranged from 32,000 to 114,000 cubic yards, with an average per job of 73,400 cubic yards.

During the 1978 dredging season, three cuts were dredged to 12 feet with the WILLIAM A. THOMPSON, removing 57,294 cubic yards of dredged material. Work began on 27 September 1978 and terminated on 6 October 1978. Placement of the dredged material was on an island at river mile 664.3, on the right descending bank in Iowa. The disposal was in a diked containment area of about 3.5 acres with a capacity of about 60,000 cubic yards. This area had previously been used for dredged material disposal, and approximately one-half of the island was bare sand.

EXPERIMENTAL DESIGN

Sediment. Prior to dredging operations, three sediment samples were collected with a Ponar bottom sampler from the area to be dredged (Figure 14). Particle size analysis was conducted on all sediment samples.

Areal Extent. Discrete water samples were collected during dredging operations on 28 September 1978 for analysis of turbidity and total suspended solids. Sample sites were located on transects 100, 300, 600, 1,000, 1,400, 1,500, and 2,700 feet downstream from the effluent pipe

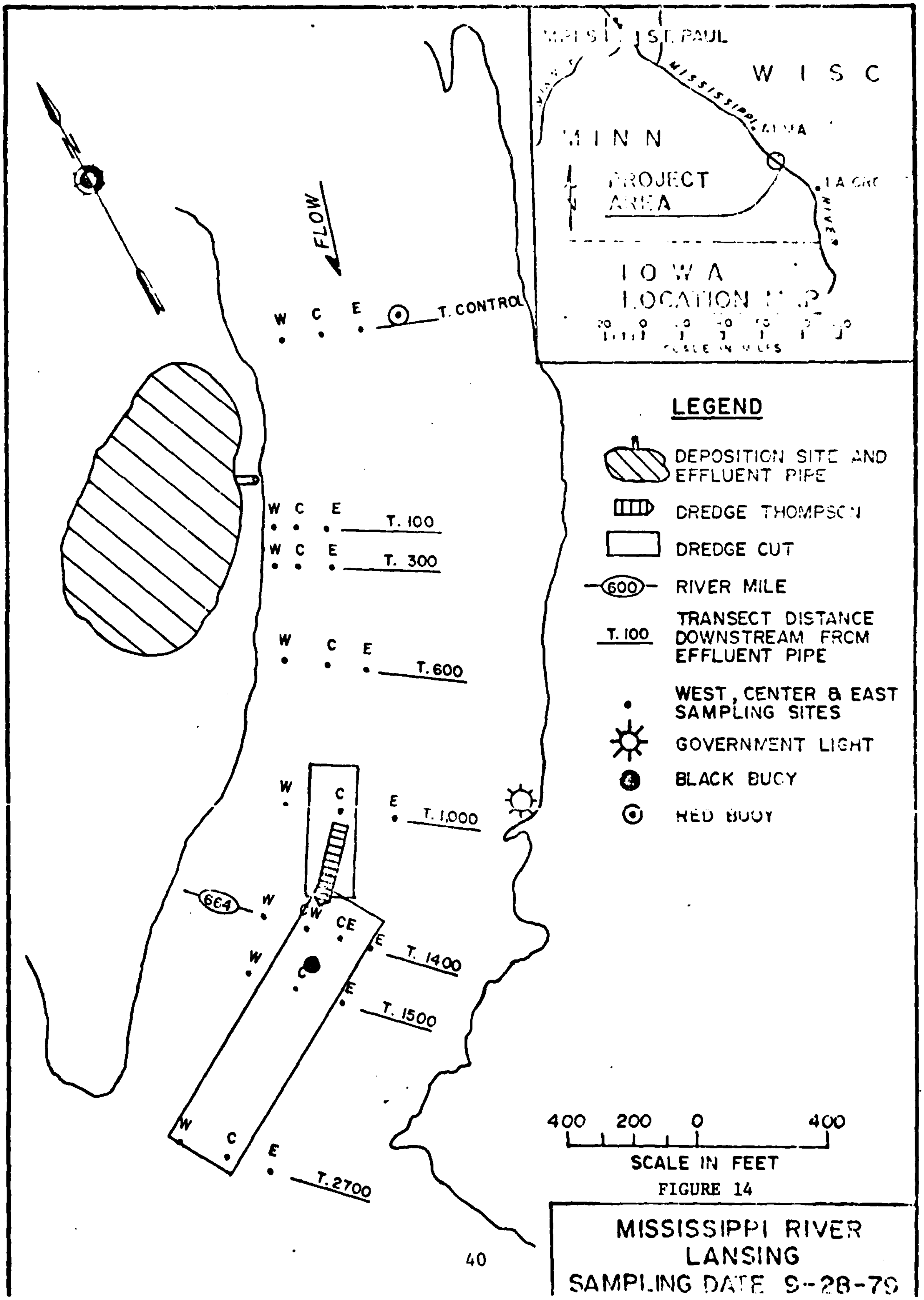


FIGURE 14

MISSISSIPPI RIVER
LANSING
SAMPLING DATE 9-28-79

located at the on-land disposal area. The dredge was positioned between the 1,000-and 1,400-foot transects. One control transect was located 400 feet upstream from the disposal site. Each transect, with one exception, had three sampling sites designated east, central, and west. The 1,400-foot transect had four sites, two of which were on either side of the dredge cutterhead (Figure 14). At each site, replicate samples were collected at two depths, 1 foot from the surface and bottom. Samples were collected simultaneously from each of the sites on a transect, and at the two depths previously mentioned. A discrete water sample was also collected directly from the effluent generated from the confined on-land disposal.

Following the completion of water sampling, current velocity was measured with a pygmy current meter. Measurements were taken 1 meter from surface and bottom at two sites located 200 feet downstream from the dredge (Figure 14).

ANALYSIS METHODS

Samples were chilled after collection and shipped as soon as possible for laboratory analysis. Collection and analysis of turbidity and suspended solids samples followed guidelines set forth in the U.S. Environmental Protection Agency's "Methods for Chemical Analysis of Water and Wastes," July, 1974. Particle size analysis of sediment samples was accomplished by use of standard mesh screens and hydrometer for finer particles. Analysis was conducted by Aqua-Tech, Inc., Port Washington, Wisconsin.

RESULTS

FIELD CONDITIONS

Sample collection occurred on 28 September 1978, under sunny skies. No wind was measurable, and air temperature was about 65°F. Results of current measurements are as follows:

TABLE 10 Current measurements at Upper Lansing Light (9/28/78)

Site	Location	Velocity (ft/sec.)
1	Surface	2.93
2	Surface	2.40
1	Bottom	1.73
2	Bottom	0.83

PARTICLE SIZE ANALYSIS

The sediment samples collected from the dredge cut consisted mainly of sand-sized particles (Table 11). Medium and coarse sand comprised about 84 percent and 8 percent, respectively, of the sediments. Fine sand-sized particles made up 4 percent of the sediments. Clay, particles larger than sand, and silt made up about 2.5, 1.0, and 0.6 percent, respectively.

TABLE 11 Percent Composition of Particle Sizes of Sediments Collected from the Lansing Dredge Cut on 9/28/78 (Analysis Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin.

Classification	Sampling Site NE	Sampling Site SW	Sampling Site SE
> sand	0.26	1.32	1.37
coarse sand	5.88	9.53	8.70
medium sand	85.63	83.59	82.90
fine sand	4.63	3.56	3.45
silt	0.40	0.01	1.39
clay	3.20	1.99	2.19
Percent Summation	100.00	100.00	100.00

TURBIDITY AND SUSPENDED SOLIDS

With three exceptions, turbidity measurements were below MPCA's established standard of 25 turbidity units (NTU) (Table 12). Turbidity measurements from near surface and near bottom samples ranged from 20 to 26.5 NTU. Values in excess of the MPCA allowable limit occurred at 1400 feet distance from the effluent pipe near surface on the west transect and near bottom immediately east of the dredge cutterhead. Values in excess of the allowable limit also occurred in bottom samples located at 1500 feet on the center transect and 2700 feet on the west transect. Control values from 400 feet upstream of the dredge ranged from 19.7 to 21.8 NTU in near-surface samples and 20.3 to 22.3 NTU in near-bottom samples. The turbidity measurement (52.3 NTU) taken directly from the effluent pipe located at the on-land disposal site was in excess of the MPCA's effluent standard.

Suspended solids measurements on all transects including the control transect were above MPCA standards (30 mg/l) (Table 13). Suspended solids values ranged from 32 to 62 mg/l in surface samples, and 33 to 64 mg/l in bottom samples. Suspended solids measurements from the control transects in surface and bottom samples ranged from 38 to 55 mg/l. Suspendedsolids values from samples taken directly from the effluent pipe were 110 and 109 mg/l.

TABLE 12 Upper Lansing Light Dredge Cut (9/28/78). Comparison of Turbidity at Two Depths With Distance Downstream of the Effluent Pipe Coming from the Confined On-land Disposal Site (Analysis Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin).

Turbidity (NTU's)[1]

Transect		Surface			Bottom		
		W	C	E	W	C	E
	Control	21.8 20.9	21.0 21.7	19.7 20.7	22.0 22.3	21.0 21.2	21.2 20.3
	Effluent Pipe	52.3					
Distance from effluent pipe (feet)	100	22.7 24.3	24.3 21.5	22.2 21.3	23.5 23.7	22.0 21.7	21.3 22.7
	300	22.5 24.7	20.8 20.0	21.2 20.7	24.7 23.0	24.3 23.5	21.7 23.2
	600	22.5 22.3	21.5 23.0	20.8 20.7	21.8 23.3	23.7 22.3	22.0 21.2
Phase I	1000	21.8 22.7	21.0 21.7	20.5 20.5	21.7 22.2	21.2 21.2	21.8 21.7
Phase II	1300	Dredge Cutterhead					
	1400[2]	23.7 26.5	22.7 | 21.5 21.2 | 21.7	20.5 22.3	23.2 22.2	22.2 | 22.7 22.0 | 26.7	23.2 22.0
	1500	22.8 22.8	22.0 22.2	21.2 21.8	24.3 23.3	26.5 23.7	21.7 21.8
	2700	24.5 24.3	22.5 23.3	22.5 22.7	24.0 26.0	23.5 23.2	20.2 24.7

1 Duplicate samples at every site.

2 Four sampling sites on 1400-foot transect, two immediately on either side of the cutterhead.

TABLE 13 Upper Lansing Light Dredge Cut (9/28/78). Comparison of Suspended Solids at Two Depths With Distance Downstream of the Effluent Pipe Coming from the Confined On-land Disposal Site (Analysis Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin).

Suspended Solids (mg/l)[1]

		Surface			Bottom		
	Transect	W	C	E	W	C	E
	Control	42 40	47 49	50 38	55 42	48 51	43 38
Distance from Effluent Pipe (feet)	Effluent Pipe			110	109		
	100	44 43	48 37	33 38	52 36	53 49	39 38
	300	42 58	48 46	40 35	32 49	44 57	41 36
	600	46 49	54 49	49 40	40 55	39 38	50 35
Phase I	1000	42 40	40 50	32 34	52 51	49 50	40 39
	1300	Dredge Cutterhead					
Phase II	1400[2]	47 43	49 62 47 53	33 37	53 49	41 56 49 33	39 42
	1500	45 43	55 55	39 41	42 44	55 64	52 48
	2700	48 48	50 50	36 40	42 50	63 56	47 45

1) Duplicate samples at every site.
2) Four sampling sites on 1400-foot transect, two immediately on either side of cutterhead.

STATISTICAL EVALUATION

The study was segmented into two phases for statistical analyses. The first assessed the impacts on turbidity and suspended solids levels resulting from the effluents from the confined on-land disposal. This part included the samples from the control transect and transects located immediately downstream of the effluent pipe up to the dredge (labeled as control, 100, 300, 600, and 1000 feet on Figure 14). The second phase assessed the changes in turbidity and suspended solids resulting from the hydraulic cutterhead. This phase included control samples from the transect labeled 1000 feet on Figure 14, which was immediately upstream of the dredge, as well as samples from transects 100, 200, and 1400 feet downstream of the dredge (labeled as 1400, 1500, and 2700 feet on Figure 14). For each of the two parts, near-surface and near-bottom samples were statistically analyzed separately. Statistical outliers (which ran from 1 to 2 percent of all data) were eliminated from the statistical analyses.

Phase I. In phase I, the mean near-surface turbidity values for transects located downstream of the effluent pipe were 1 to 2 NTU higher than for the control transect (Figure 15). However, turbidity was approaching control levels 1000 feet downstream of the effluent pipe. The west location on each of the transects consistently showed the highest turbidity readings and the east position the lowest (Table 12). However, these differences with distance from the effluent pipe and sampling site location on a transect were not shown to be significant when testing with analysis of variance (Appendix Table B-1).

The near-bottom samples had turbidity values similar to the near-surface samples, for phase I. Mean near-bottom turbidity values for transects downstream of the effluent pipe were 1 to 2 NTU higher than for the control transect (Figure 16). Turbidity peaked at 300 feet from the effluent pipe and returned to control levels at 1000 feet. The west sampling site location on a transect consistently had the highest turbidity values (Table 12). By employing analysis of variance, the trends with transect distance from the effluent pipe and sampling site locations were found to be significant (Appendix Table B-2).

In phase I, the standard sampling error for turbidity was 1.9 NTU for near-surface samples and 0.69 NTU for near-bottom samples. The greater standard sampling error for near-surface samples indicates greater fluctuations between replicate samples near the surface than near the bottom. The small standard error for near-bottom samples allowed for the differences in turbidity values due to transect distance from the effluent pipe and sampling site location on a transect to be resolved by analysis of variance.

When the mean near-surface suspended solids concentrations for each transect from phase I are compared, no trend with distance up or downstream of the effluent pipe can be seen (Figure 17). The east sampling site location on a transect consistently had the lowest suspended solids concentrations (Table 13). Testing with analysis of variance found that there were no significant differences in suspended solids concentrations due to transect distance from the effluent pipe. However, differences due to sampling site position were shown to be significant with the east sampling site location having the lowest concentrations (Appendix Table B-3). The mean for all near-surface suspended solids data from phase I is 43.4 mg/l, with a standard sampling error of 5.2 mg/l.

The mean near-bottom suspended solids concentrations for transects located downstream of the effluent pipe ranged from 42.8 to 46.8 mg/l compared to the mean of the control transect samples, 46 mg/l (Figure 18). Figure 18 shows a decrease in suspended solids from the control down to 600 feet below the effluent pipe, with a return to control levels at 1000 feet. As was seen for the near-surface suspended solids, near-bottom suspended solids concentrations were consistently lowest for the east location on a transect (Table 13). Analysis of variance indicated no significant differences due to distance from the disposal site, but a significant difference based on lateral sampling site location (Appendix B, Table B-4).

The mean suspended solids concentrations of all near-bottom samples from phase I (44.7 mg/l) was slightly higher than the overall mean near-surface concentration (43.4 mg/l). The standard sampling error for near-bottom samples (6.8 mg/l) was larger than for the near-surface samples (5.2 mg/l), indicating greater variability in the near-bottom sample.

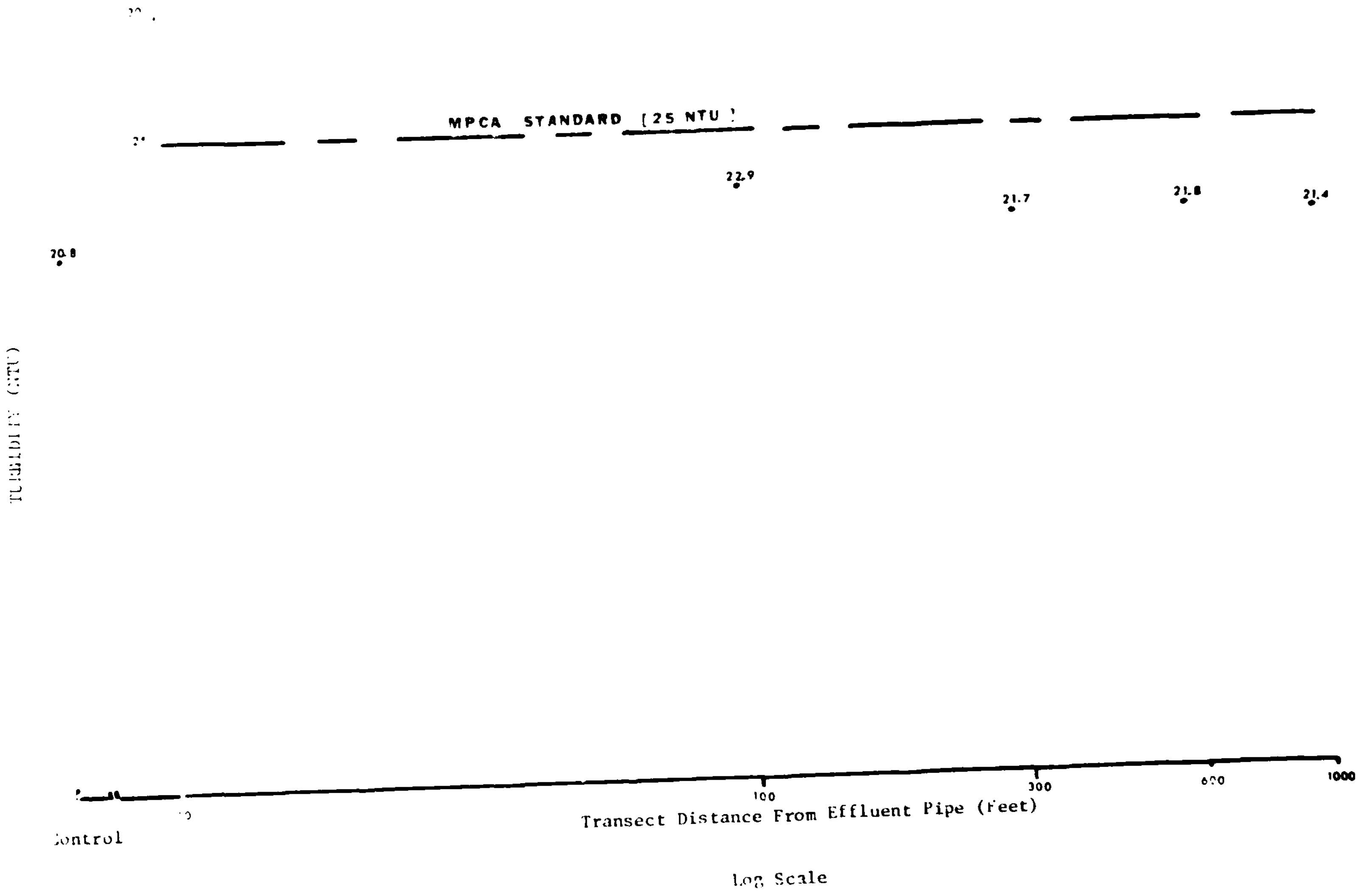
Phase II. The second phase of the study conducted at the Upper Lansing Light dredge cut was aimed at assessing the impacts on water quality resulting from the hydraulic cutterhead. Near the surface, mean turbidity levels for transects downstream of the cutterhead were 1 to 2 NTU higher than the mean for the transect located immediately upstream of the cutterhead (Figure 19). The west location on each of the transects had the highest values and the east location the lowest (Table 12). Testing with analysis of variance, differences in turbidity values due to transect distance from the cutterhead and sampling site position on a transect were both found to be significant (Appendix Table B-5).

Mean near-bottom turbidity values for transects located downstream of the dredge were 1 to 2 NTU higher than the mean for the control transect (Figure 20). However, statistical testing of the near-bottom turbidity by analysis of variance indicated no significant differences due to transect distance from the cutterhead or lateral sampling site location on a transect (Appendix Table B-6).

Comparing the standard sampling errors for turbidity for near-surface samples and near-bottom samples shows a trend opposite that seen for samples below the effluent pipe. The standard sampling error for turbidity for near-surface samples (.78) was less than for near-bottom samples (1.86). This would indicate that the turbidity plume below the dredge was more consistent and uniform near the surface than near the bottom whereas, below the effluent pipe, the turbidity plume was more consistent and uniform near the bottom than near the surface.

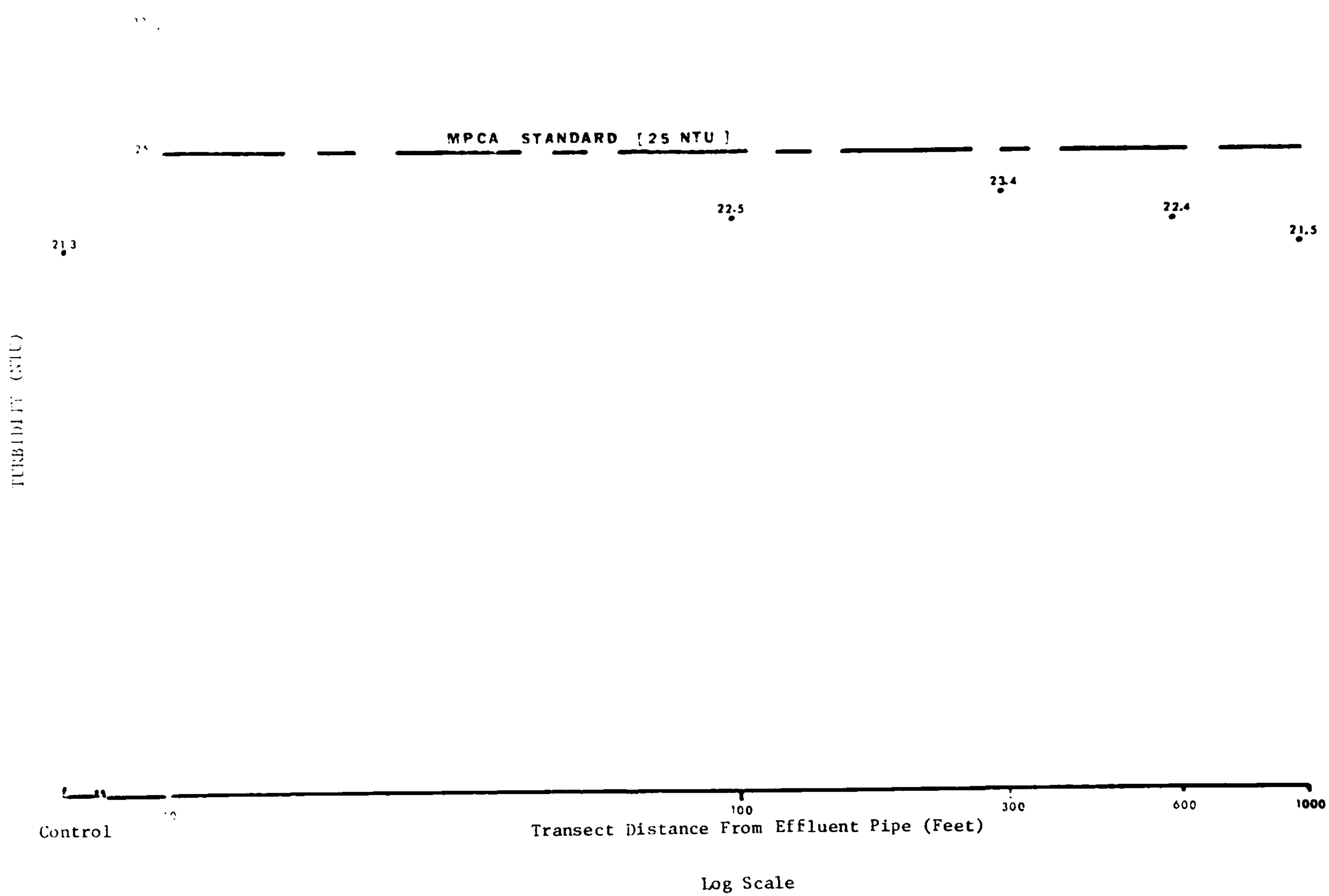
In phase II, mean near-surface suspended solids concentrations from transects located downstream of the dredge ranged from 45.8 to 50.8 mg/l compared to the mean value from the control transect of 46.8 mg/l (Figure 21). In addition, the center location on the transect had the highest near-surface suspended solids concentrations (Table 13).

FIGURE 15 Mean* near-surface turbidity values (NTU) from transects downstream of effluent pipe at Lansing on Mississippi River, Phase I, 9-28-78



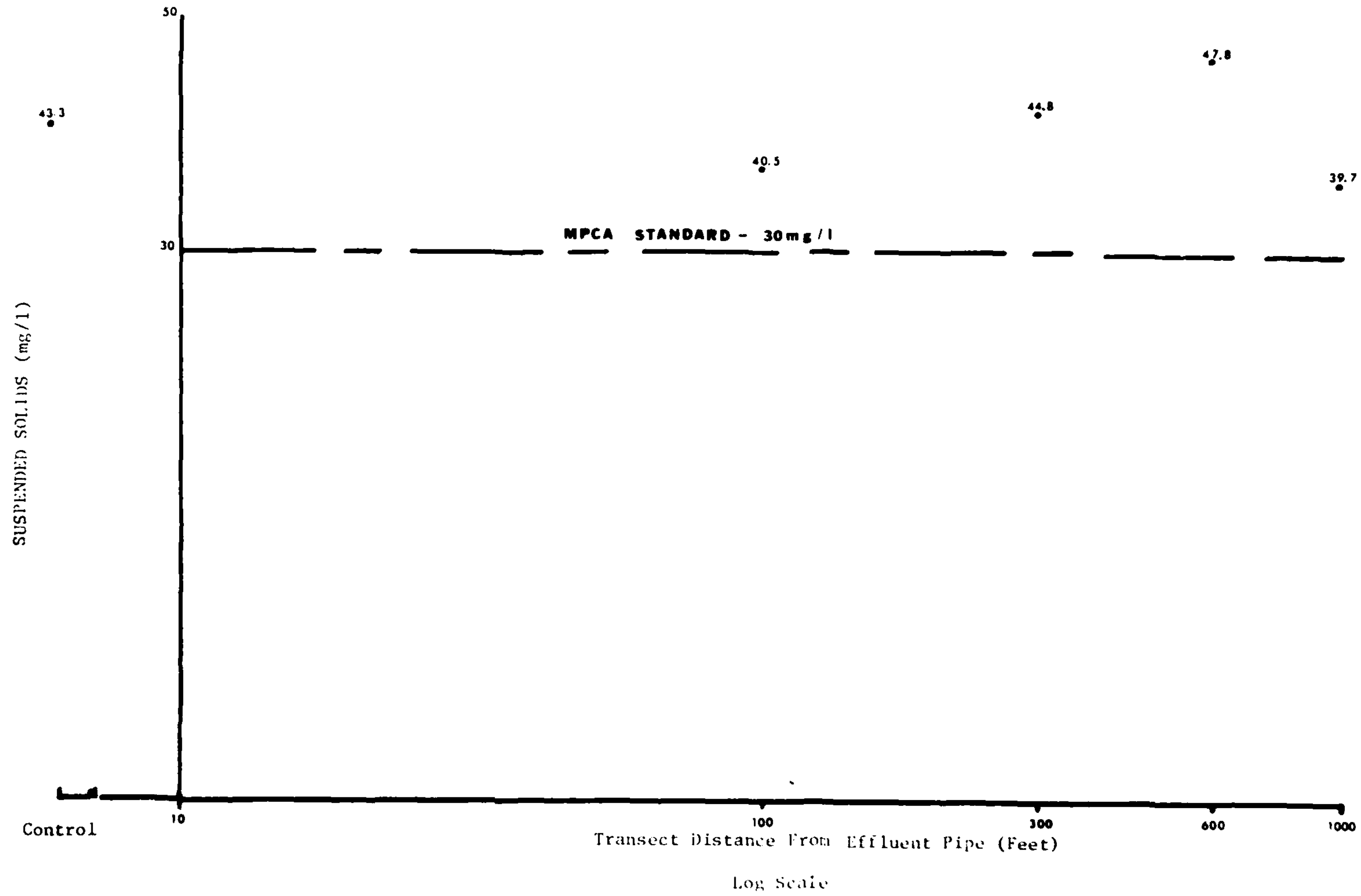
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 16 Mean* near-bottom turbidity values (NTU) from transects downstream of effluent pipe at Lansing on Mississippi River, Phase I, 9-28-78



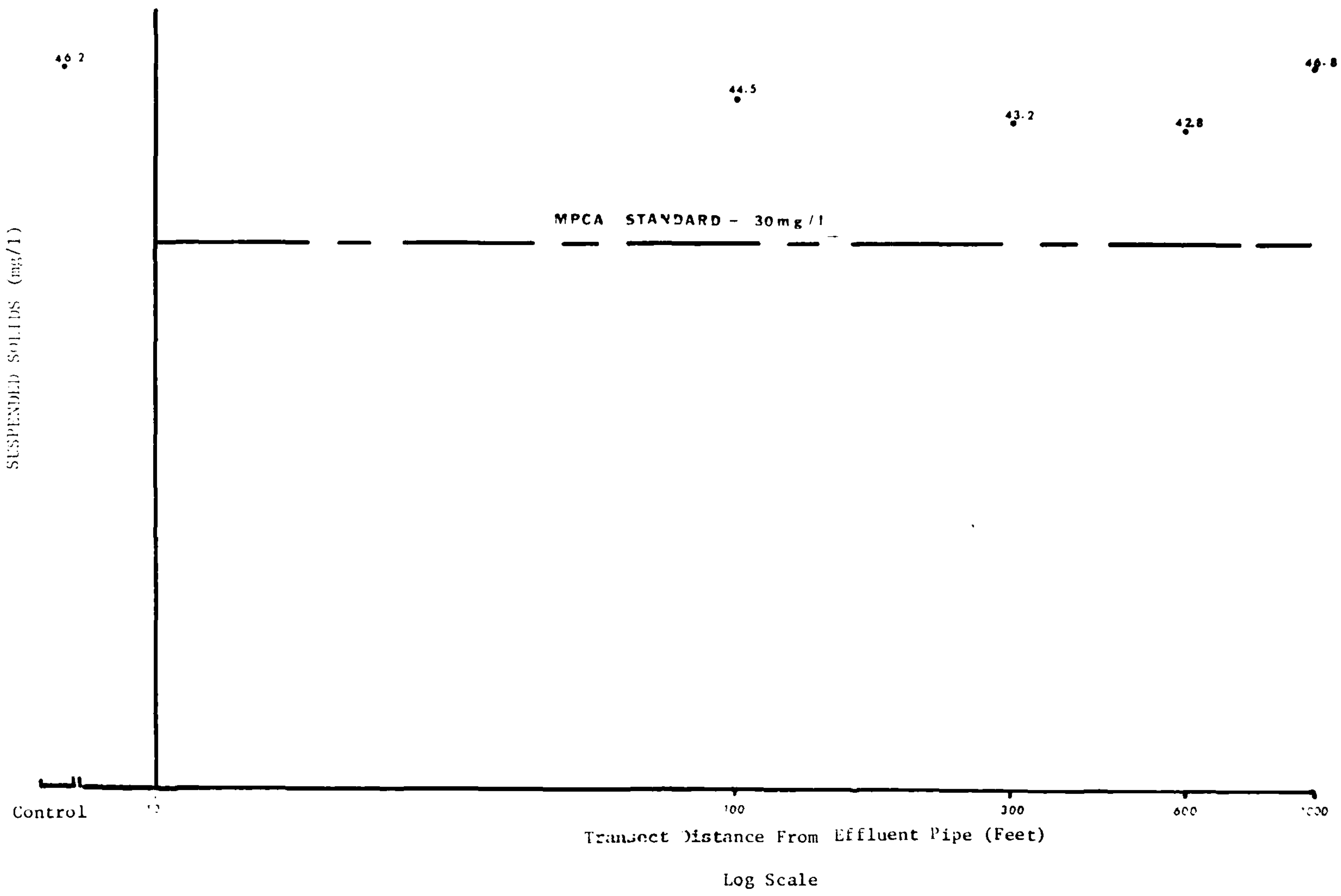
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 17 Mean* near-surface suspended solids values (mg/l) from transects downstream of effluent pipe at Lansing on Mississippi River, Phase I, 9-28-78



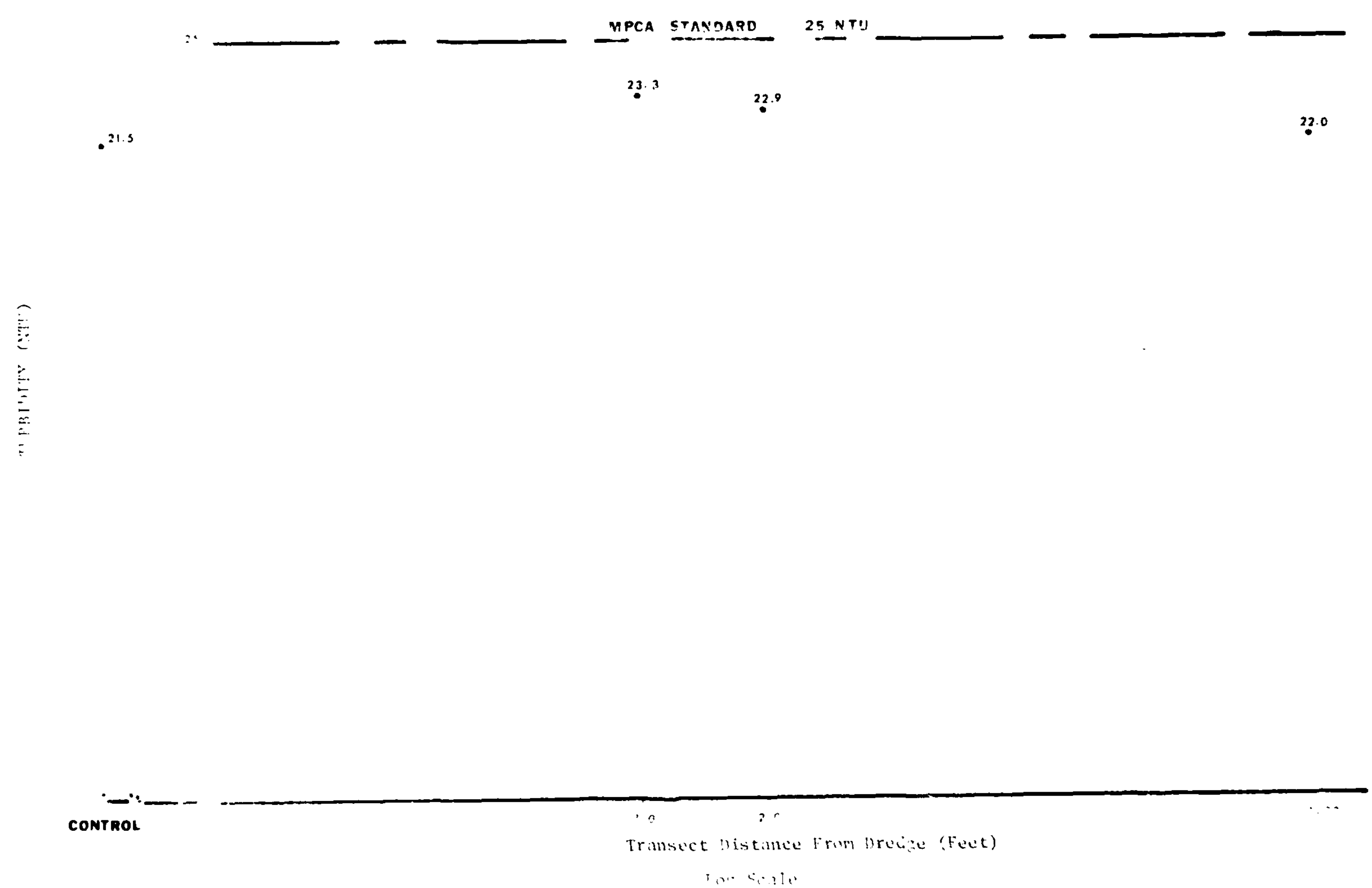
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 13 Mean* near-bottom suspended solids values (mg/l) from transects downstream of effluent pipe at Lansing on Mississippi River, Phase 1, 9-28-78



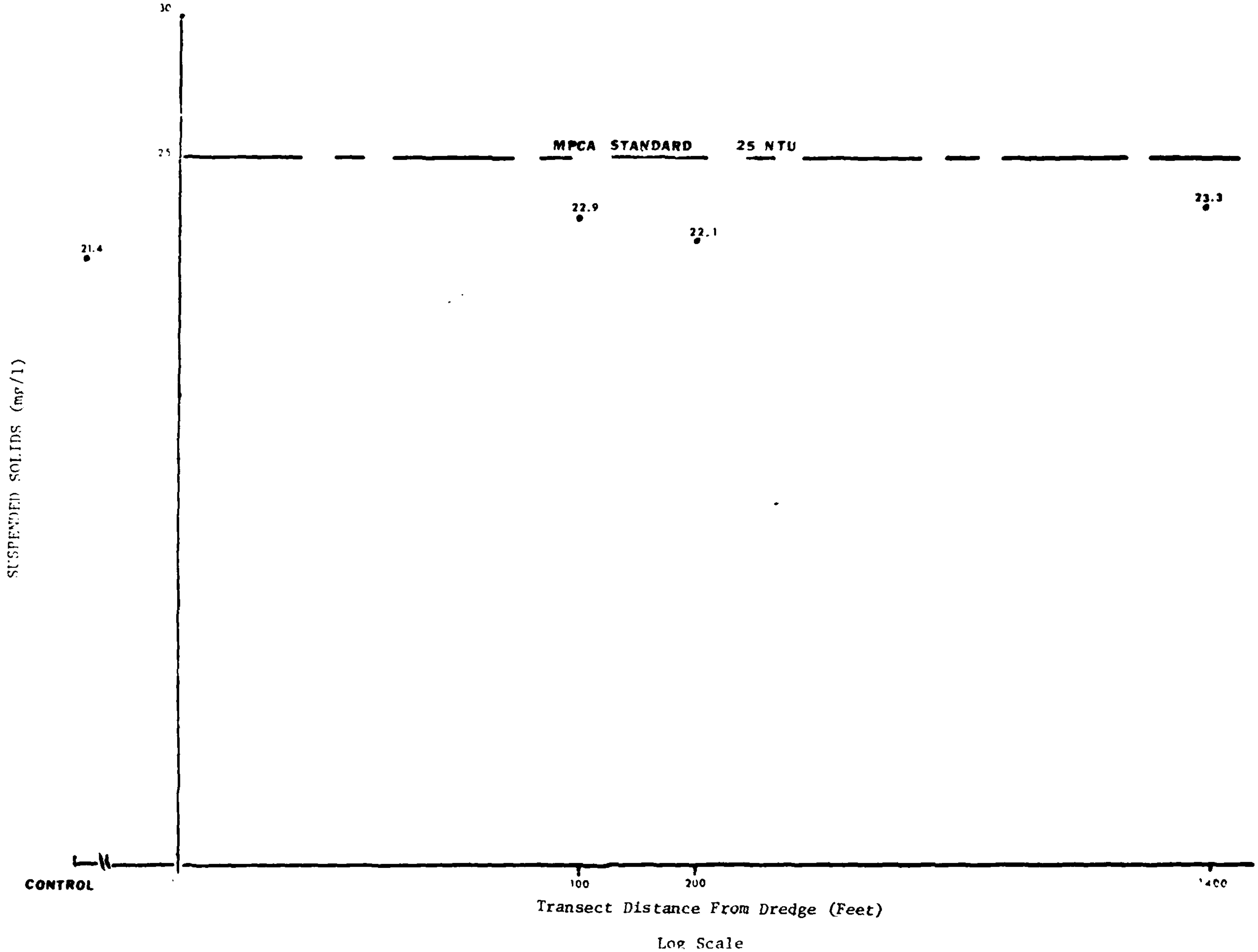
*Data represents arithmetic mean of water samples collected from three sites on each transect.

Figure 19. Mean near-surface turbidity values [illegible] [illegible] of dredge cutterhead at Lansing, Phase II, 9-28-78



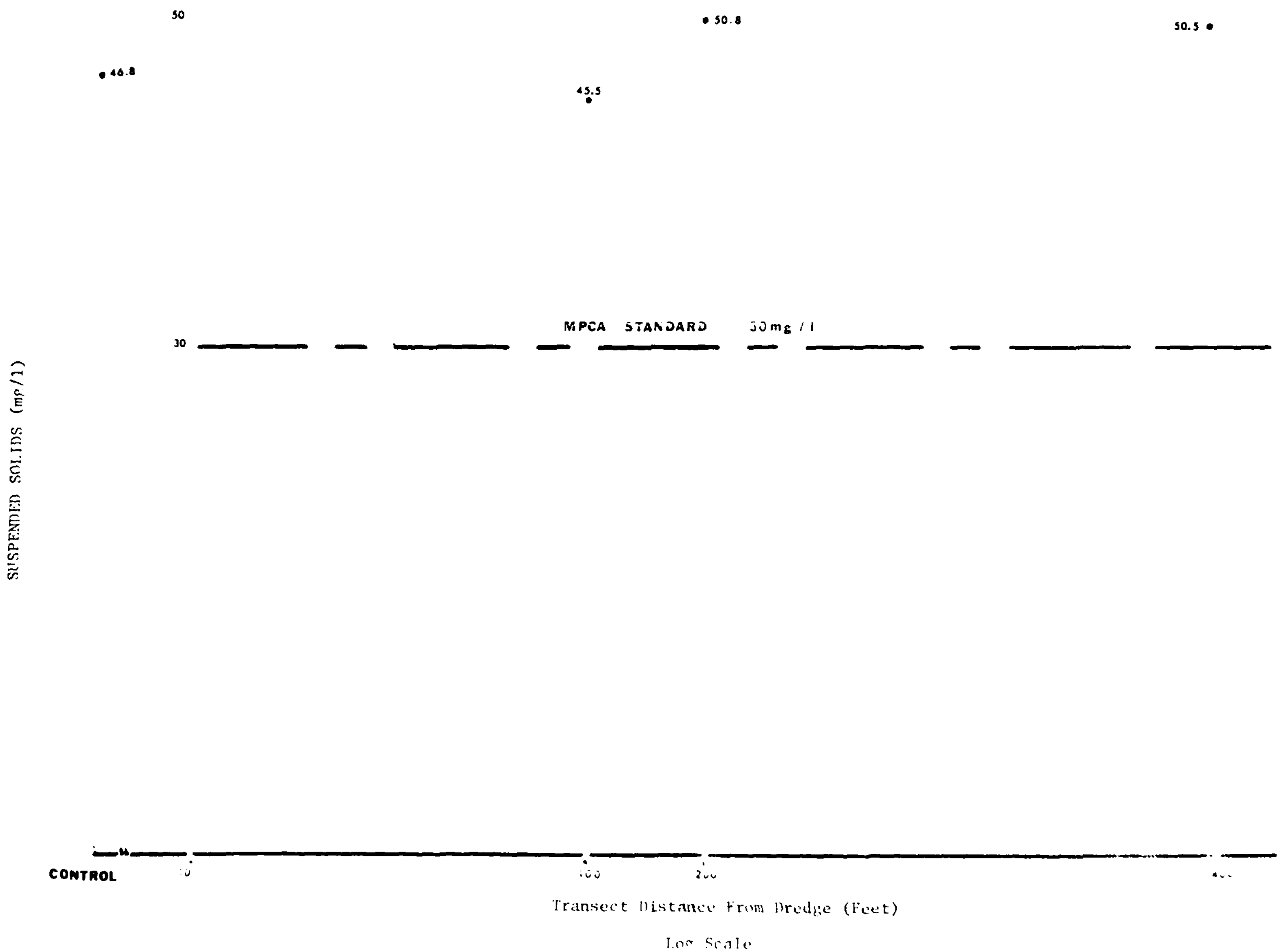
*Data represents arithmetic mean of water samples collected from four sites on each transect.

FIGURE 20 Mean* near-bottom turbidity values (NTU) for transects downstream of dredge cutterhead at Lansing, Phase II, 9-28-78



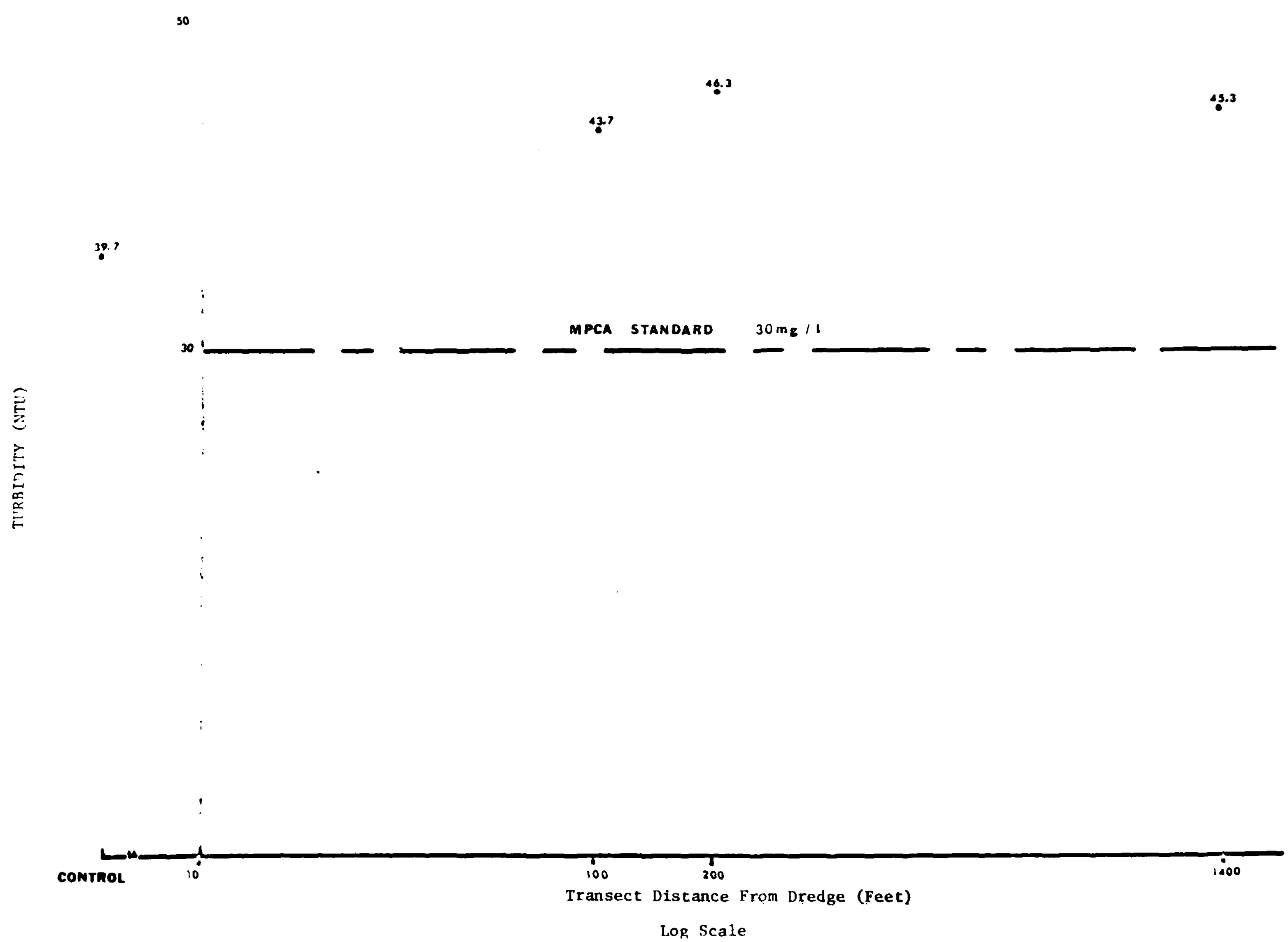
*Data represents arithmetic mean of water samples collected from four sites on each transect.

FIGURE 21 Mean* near-surface suspended solids values (mg/l) for transects downstream of dredge cutterhead at Lansing Phase II, 9-28-78



*Data represents arithmetic mean of water samples collected from four sites on each transect.

FIGURE 22 Mean* near-bottom suspended solids (mg/l) for transects downstream of dredge cutterhead at Lansing, Phase II, 9-28-78



*Data represents arithmetic mean of water samples collected from four sites on each transect.

In testing with analysis of variance, differences in suspended solids concentrations due to transect distance from the dredge cutterhead and sampling site location on a transect were both significant (Appendix Table B-7).

Near-bottom suspended solids concentrations did not show any trends with distance from the dredge, being lowest near the dredge and highest farthest from the dredge (Figure 22). The center locations on the transects had the highest concentrations and the east locations the lowest (Table 13). Analysis of variance indicated no significant trends with distance from the cutterhead. However, there was a highly significant difference due to lateral sampling site location on a transect (Appendix B Table B-8). Analysis of variance also yielded a significant interaction between sampling site location and transect distance from the cutterhead. The significant interaction is due to the unpredictability of any pattern with distance from the cutterhead.

A comparison of standard sampling error for suspended solids from the two parts (Table 14), indicates that there were greater variations in suspended solids concentration below the disposal pipe than below the dredge cutterhead. In addition, both in the disposal plume and the dredge plume, greater variability was noted in near-bottom samples than in near-surface samples.

TABLE 14 Standard sampling error for suspended solids concentrations at Upper Lansing Light, Phases I and II.

		Near-surface	Near-bottom
Phase I	Below effluent pipe	5.2	6.8
Phase II	Below dredge cutterhead	2.74	3.59

SUMMARY OF FINDINGS

1. The sediments in the dredge cut were very coarse, mainly consisting of medium to coarse sand-sized particles, with only traces of silt and clay-sized particles (about 3 percent). Because of the relatively low percentages of clays and silts, there is very little potential for major elevations in turbidity and suspended solids when the sediments are resuspended.

2. Water samples collected during this study upstream of the dredging and disposal operations indicated that ambient conditions for turbidity and suspended solids were already high. This finding may be attributable to the high current velocities on the day of the sampling, averaging 2.66 feet/second near the surface and 1.28 feet/second near the bottom.

3. Turbidity measurements, with the exception of four sites which were located downstream of the hydraulic cutterhead, were below MPCA's established standard of 25 turbidity units and ranged from 20 to 26.5 NTU. Suspended solids measurements, including the control sites, were above MPCA's standard of 30 mg/l and ranged from 32 to 64 mg/l.

4. Effluent collected directly from the effluent pipe had turbidity and suspended solids values approximately double those of ambient river water. This would indicate that the effluent pipe was acting as a point discharge for turbidity and suspended solids.

5. Turbidity downstream of the effluent pipe was elevated over the control samples an average of 1 to 2 NTU both near the surface and near the bottom. In addition, the west sampling sites on the transects showed the highest turbidity values for both near-surface and near-bottom samples. Both of these trends, with transect distance and sampling site position on a transect, were found to be significant in testing with analysis of variance for the near-bottom samples. In the near-surface samples, the trends were not shown to be significant. Both the near-surface and near-bottom disposal plume had returned to control levels 1,000 feet downstream of the effluent pipe.

6. Suspended solids did not show any trends with transect distance from the effluent pipe for the near-surface or near-bottom samples. Suspended solids showed variability with sampling site position on a transect, the east location on a transect consistently showing the lowest values. Testing with analysis of variance showed that trends with transect distance from the disposal pipe were not significant, but trends with lateral sampling site location on a transect were.

7. Below the hydraulic cutterhead, in near-surface and near-bottom samples, an average of 1 to 2 NTU elevation above the control was noted. Near-surface turbidity values showed variability with sampling site position on a transect, with the east location showing the lowest readings. Through analysis of variance the above trends were found to be significant for near-surface samples, but not for near-bottom samples.

8. Suspended solids below the hydraulic cutterhead near the surface showed a significant elevation above control values. In addition, the center position on the transects showed the significantly highest concentration. Near the bottom, suspended solids values did not show any trends with distance from the dredge, being lowest near the dredge and highest farthest from the dredge. However, suspended solids values did vary significantly with sampling site on a transect. As in the near surface samples, near bottom suspended solids values for the center position on the transect were highest in concentration.

9. A comparison of standard sampling errors, which is a measure of variability between replicate samples, indicated that turbidity near the surface below the disposal pipe and turbidity near the bottom below the cutterhead showed the greatest variability among replicate samples.

10. A comparison of standard sampling errors for suspended solids indicated that there was less uniformity between replicate samples below the disposal pipe than below the cutterhead. In both cases, near-bottom samples showed greater variability than near-surface samples.

CONCLUSIONS

Turbidity increased downstream of the confined on-land disposal pipe and downstream of the hydraulic cutterhead by approximately 1 or 2 NTU. The effects of the disposal pipe on turbidity were mainly limited to immediately adjacent the confined on-land disposal site, with very little spreading into the main channel. In addition, 1000 feet downstream of the disposal pipe, turbidity had returned to upstream control levels. Below the hydraulic cutterhead, there was a significant elevation in turbidity in comparison with upstream control values. The effects of the hydraulic cutterhead on turbidity were mainly limited to the center of the channel and extended out to 1400 feet. Turbidity values exceeding the MPCA established standard of 25 NTU occurred in only four samples, all downstream of the hydraulic cutterhead.

Suspended solids data did not show patterns as consistent as those of the turbidity data. Although no significant increases were found below the effluent pipe, significant increases were found downstream of the hydraulic cutterhead. All samples, including control samples, had suspended solids values exceeding the MPCA established standard of 30 mg/l.

Although significant increases in turbidity and suspended solids were found, actual elevations were small, probably attributable to the coarseness of the sediments being dredged at this site.

POOL 1 (RIVER MILE 852)
MONITORING OF TURBIDITY AND SUSPENDED SOLIDS CHANGES FROM CLAMSHELL DREDGING OPERATIONS

OBJECTIVE

The objective of this study was to monitor turbidity and suspended solids changes in water quality, resulting from clamshell dredging operations in Pool 1 of the Upper Mississippi River.

METHODS

DESCRIPTION OF SAMPLING SITES

The Franklin Avenue Bridge dredge site is located in Pool 1 between the Franklin and Washington Avenue Bridges at river mile 852. This dredge site is located in the heart of the Twin Cities Metropolitan Area. It is subject to frequent dredging, averaging once every 2 years. From 1956 to 1977, the quantity of material dredged per job at this site ranged from 5,000 to 159,000 cubic yards and averaged 37,900 cubic yards per job.

During the 1978 maintenance dredging season, nine cuts at the Franklin Avenue Bridge site were clamshell dredged to a depth of 12 feet. In all of Pool 1, a total of 59,858 cubic yards of material was removed in 1978. The dredge operated in Pool 1 from 21 August to 30 September 1978.

Disposal of dredged material occurred on-land, with direct unloading. The city of Minneapolis provided a placement site at the old municipal coal terminal located above the Washington Avenue Bridge on the right descending bank at river mile 852.7.

EXPERIMENTAL DESIGN

Sediment. Three sediment samples were collected with a Ponar bottom sampler from the area being dredged. Particle size analysis was conducted on all samples.

Areal Extent. Discrete water samples were collected during dredging operations on 25 and 26 August 1978 for analysis of turbidity and total suspended solids. The water sampling program consisted of three sampling phases. In the first phase, samples were collected on 25 August 1978 from sites located on four transects: 25, 150, 250, and 550 feet downstream from the dredging operation, and on one control transect located 425 feet upstream of the dredge (Figure 23). Each transect had three lateral sampling sites designated east, central, and west. At each site, samples were collected at two depths, 1 foot from the surface and 1 foot from the bottom. Samples were collected simultaneously at each of the three sites on a transect and at the two depths stated.

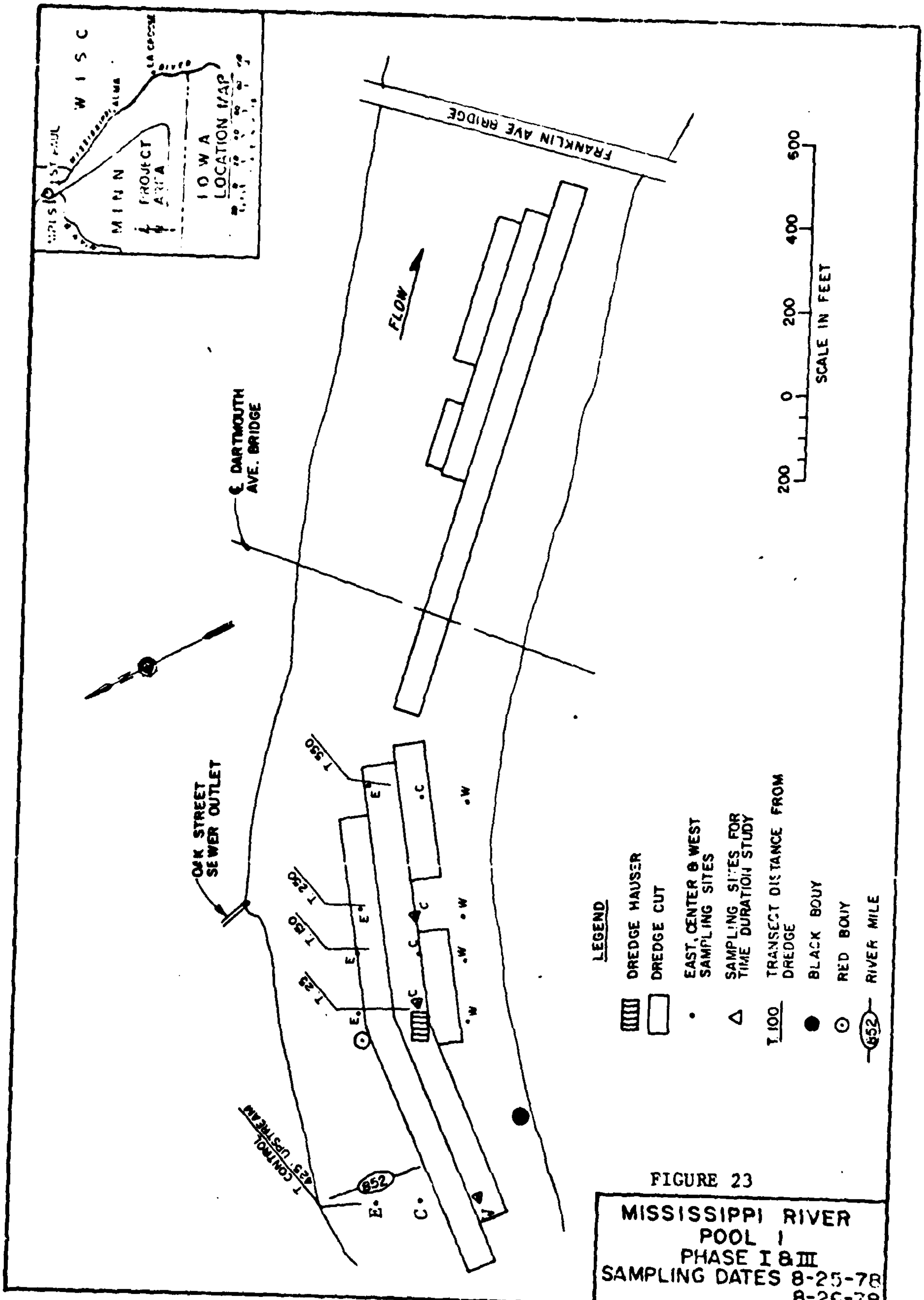


FIGURE 23

MISSISSIPPI RIVER
POOL I
PHASE I & III
SAMPLING DATES 8-25-78
8-26-78

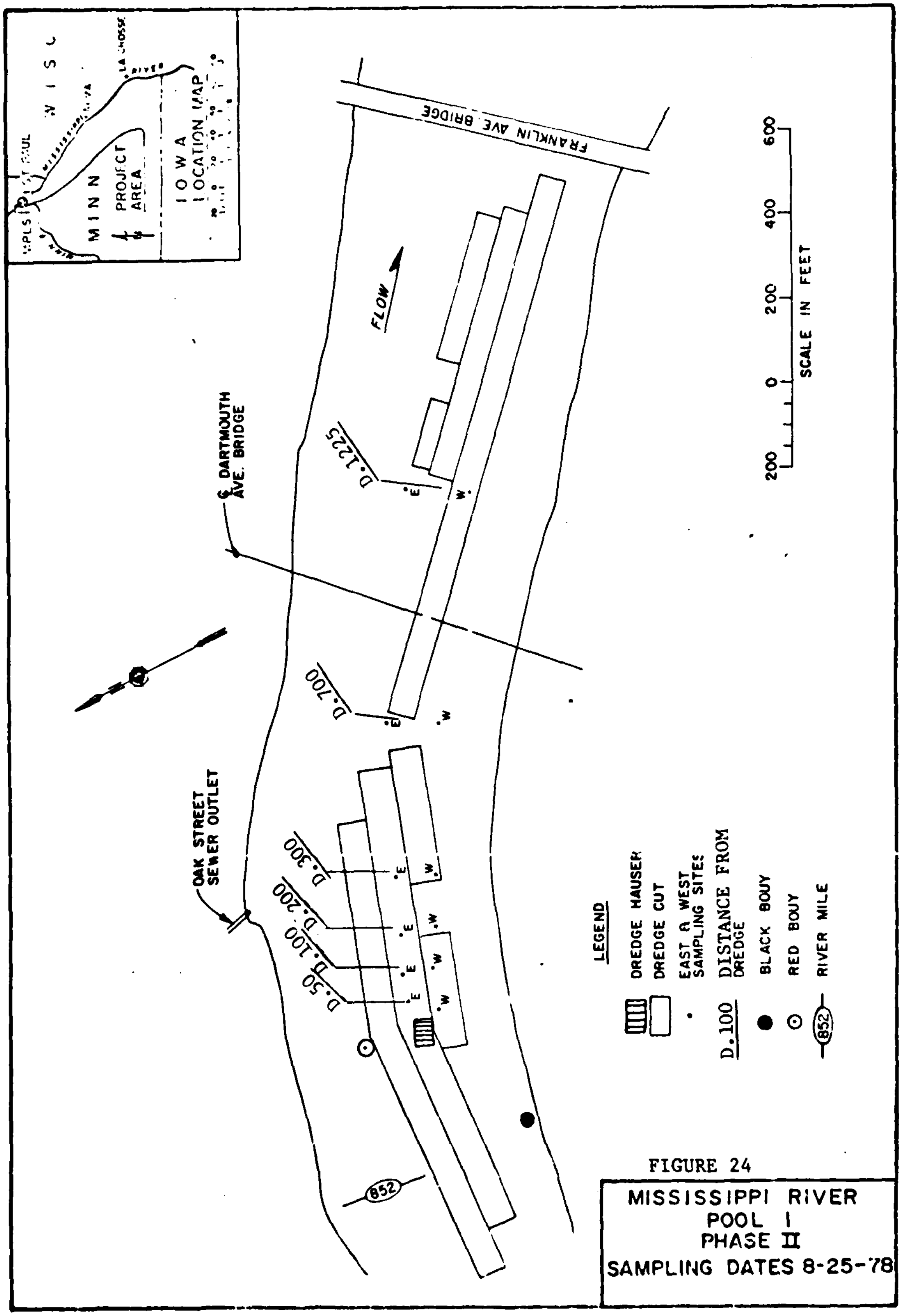


FIGURE 24

MISSISSIPPI RIVER
POOL I
PHASE II
SAMPLING DATES 8-25-78

In the second phase (conducted 25 August 78), sample sites were located on two radials oriented downstream from the dredge operation (Figure 24). Each radial had six sampling sites located at 50, 100, 200, 300, 700, and 1,225 feet from the dredging operation. At each site, water samples were collected at two depths, 1 foot from the surface and 1 foot from the bottom. Samples from the east radial were collected prior to samples from the west radial. On each of the radials, samples were collected simultaneously at the three sites located furthest downstream (300, 700, and 1,225 feet from the dredge), and at the two depths noted. Following this collection, samples were obtained simultaneously from the sites on each radial closest to the dredge (50, 100, and 200 feet distance), and at the two depths noted. Following the completion of this phase, current velocity was measured with a pygmy current meter. Measurements were taken at two depths and two sites, located 200 feet downstream of the dredge (Figure 24).

Time Duration. In the third phase, samples were collected over designated time intervals after dredging at three sites, at depths 1 foot from the surface and 1 foot from the bottom. The three sites were located at one of the control sites and at two sites downstream of the dredge (Figure 23).

ANALYSIS METHODS

Samples were chilled after collection and shipped as soon as possible for laboratory analyses. Collection and analyses of turbidity and suspended solids samples followed guidelines set forth in the U.S. Environmental Protection Agency's "Methods For Chemical Analysis of Water and Wastes," July 1974. Particle size analysis of sediment samples was accomplished by use of standard mesh screens and a hydrometer for finer particles. Analyses were conducted by Aqua-Tech, Inc., Port Washington, Wisconsin.

RESULTS

FIELD CONDITIONS

Sample collection occurred on 25 and 26 August 1978, under sunny skies. Air temperature ranged from 50 to 70°F during daylight and night sampling. Conditions were calm; no wind was detected; and wave height was minimal. Results of current measurements are shown in Table 15:

TABLE 15 Current Measurements in Pool 1 (River Mile 852)

Site	Depth	Velocity (ft/Sec.)
1	Surface	0.63
2	Surface	0.83
1	Bottom	0.30
2	Bottom	0.37

SEDIMENT PARTICLE SIZE

The sediment samples collected from the dredge cut consisted mainly of sand-sized particles (Table 16). Coarse and medium sand formed about 65 percent and 27 percent of the sediments, respectively. Clay-sized particles made up about 5.4 percent of the sediment and were more abundant than particles larger than sand, fine sand, or silt-sized particles (1.02, 0.65, and 0.4 percent, respectively).

TABLE 16 Percent Composition of Particle Sizes of Sediments Collected from Pool 1 on 8/25/78 (Analysis Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin).

Classification	Sampling Site #1	Sampling Site #2	Sampling Site #3
> sand	0.00	0.07	2.99
coarse sand	22.24	45.74	27.23
medium sand	69.35	47.99	65.23
fine sand	1.61	0.01	.65
silt	0.20	0.20	0.80
clay	6.60	5.80	5.4
Percent Summation	100.00	99.81	100.00

TABLE 17 **Pool 1 Dredge Site** (8/25/78). Sampling Phase I: Comparison of **Turbidity and** Suspended Solids At Two Depths with Distance Downstream of a Clamshell Dredging Operation (Analyses Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin).

TABLE 17A Turbidity (NTU)

		Surface			Bottom		
	Transect	T. West	T. Center	T. East	T. West	T. Center	T. Ea
Distance from Dredge (feet)	Control	7.9	7.1	8.3	8.1	7.3	8.3
	25	7.3	7.5	8.6	5.3	7.2	13.5
	150	7.4	6.7	8.2	6.0	7.9	8.1
	250	7.5	7.0	6.9	6.9	6.7	10.4
	550	9.8	6.6	7.1	5.9	5.9	7.7

TABLE 17B Suspended Solids (mg/l)

		Surface			Bottom		
	Transect	T. West	T. Center	T. East	T. West	T. Center	T. Eas
Distance from Dredge (feet)	Control	24	17	22	25	22	30
	25	30	19	18	20	29	27
	150	29	19	22	20	31	28
	250	29	15	22	31	33	28
	550	27	39	24	29	30	26

TABLE 18 Pool 1 Dredge Site (8/25/78). Sampling Phase II: Comparison of Turbidity and Suspended Solids at Two Depths with Distance Downstream of a Clamshell Dredging Operation (Analyses Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin).

TABLE 18A Turbidity (NTU)

<table>
<tr><th colspan="2"></th><th colspan="2">Surface</th><th colspan="2">Bottom</th></tr>
<tr><th colspan="2">Transect</th><th>Rad. East</th><th>Rad. West</th><th>Rad. East</th><th>Rad. West</th></tr>
<tr><td rowspan="7">Distance from Dredge (feet)</td><td>Control</td><td colspan="2">7.9 7.1 8.3</td><td colspan="2">8.1 7.3 8.3</td></tr>
<tr><td>50</td><td>6.3</td><td>6.7</td><td>8.3</td><td>8.0</td></tr>
<tr><td>100</td><td>6.3</td><td>7.3</td><td>6.9</td><td>6.8</td></tr>
<tr><td>200</td><td>7.5</td><td>4.5</td><td>7.2</td><td>6.1</td></tr>
<tr><td>350</td><td>5.8</td><td>8.1</td><td>5.6</td><td>6.5</td></tr>
<tr><td>750</td><td>6.9</td><td>6.5</td><td>6.9</td><td>7.5</td></tr>
<tr><td>1225</td><td>5.2</td><td>6.7</td><td>6.7</td><td>6.5</td></tr>
</table>

TABLE 18B Suspended Solids (mg/1)

<table>
<tr><th colspan="2"></th><th colspan="2">Surface</th><th colspan="2">Bottom</th></tr>
<tr><th colspan="2">Transect</th><th>Rad. East</th><th>Rad. West</th><th>Rad. East</th><th>Rad. West</th></tr>
<tr><td rowspan="7">Distance from Dredge (feet)</td><td>Control</td><td colspan="2">24 17 22</td><td colspan="2">25 22 30</td></tr>
<tr><td>50</td><td>13</td><td>33</td><td>25</td><td>33</td></tr>
<tr><td>100</td><td>18</td><td>32</td><td>20</td><td>19</td></tr>
<tr><td>200</td><td>34</td><td>23</td><td>22</td><td>32</td></tr>
<tr><td>350</td><td>17</td><td>28</td><td>23</td><td>32</td></tr>
<tr><td>750</td><td>20</td><td>27</td><td>30</td><td>36</td></tr>
<tr><td>1225</td><td>27</td><td>19</td><td>24</td><td>11</td></tr>
</table>

TABLE 19 Pool 1 Dredge Site. Phase III: Comparison of Turbidity and Suspended Solids Changes Over Time After Dredging at Three Sites (8/26/78). (Analysis Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin.)

TABLE 19A Turbidity (NTU)

		Surface			Bottom		
Sampling Sites		TD-Control	TD-25	TD-255	TD-Control	TD-25	TD-255
Time After Dredging (Hours)*	½	7.4	6.8	7.6	8.0	8.0	7.5
	1	6.8	8.2	8.1	6.8	6.9	7.9
	1½	7.9	8.1	7.3	6.8	8.6	14.3
	2½	6.9	7.0	7.9	6.9	13.0	7.7
	4½	5.6	8.2	7.6	6.3	8.6	7.0

TABLE 19B Suspended Solids (mg/l)

		Surface			Bottom		
Sampling Sites		TD-Control	TD-25	TD-255	TD-Control	TD-25	TD-255
Time After Dredging (Hours)*	½	23	15	10	16	22	26
	1	23	13	19	27	24	13
	1½	18	11	18	19	13	18
	2½	25	17	14	24	20	14
	4½	24	11	18	23	24	22

* Times are approximate. See Appendix H for contractor's report denoting precise times.

TURBIDITY AND SUSPENDED SOLIDS

In the first sampling phase, turbidity values ranged from 5.3 to 13.5 NTU, well below the established MPCA water quality standards of 25 turbidity units (Table 17A). Suspended solids measurements from the first sampling phase ranged from 15 to 39 mg/l (Table 17B). Values in excess of MPCA's standard for suspended solids (30 mg/l) were detected in one case near the surface (39 mg/l) at 550 feet from the dredge, in one case near the bottom at 150 feet (31 mg/l) and in two cases near the bottom at 250 feet distance from dredge (31 and 33 mg/l, respectively). (Table 17B).

Turbidity values from the second sampling phase showed little variation, ranging from 5.2 to 8.3 NTU (Table 18A). Suspended solids values showed more fluctuation than turbidity, ranging from 11 to 36 mg/l (Table 18B). Seven water samples in excess of the MPCA standard of 30 mg/l were noted. Three of these were found in near-surface samples and four in near-bottom samples. Very few patterns are observable in comparisons between the values in excess of the MPCA standards and the sampling distance downstream of the dredging operation.

In the third phase of the study (Table 19A), turbidity measurements collected over time after dredging ranged from 5.6 to 8.2 NTU in near-surface samples, and 6.3 to 14.3 NTU in near-bottom samples. Suspended solids measurements collected over time after dredging in the third phase of sampling were all below MPCA standards. Suspended solids values ranged from 10 to 25 mg/l in surface samples and 13 to 27 mg/l in bottom samples (Table 19B).

STATISTICAL ANALYSIS

Phase I. In phase I, analysis of variance (ANOVA) was conducted on turbidity and suspended solids data collected at two depths from sites on four transects located at increasing distances from the dredge and on one control transect. The variables analyzed were transect distance (i.e., the control transect 420 feet upstream of the dredge and transects 25, 150, 250, and 550 feet downstream from the dredge) and site location (i.e., east, center, west) on the transect. Data from near-surface and near-bottom samples were considered separately.

Statistical analysis of near-surface turbidity data showed that the distance of the transect from the dredge had no effect on turbidity (Appendix Table C-1). A comparison of turbidity levels (Figure 25) from the control transect to overall mean concentrations for transects downstream of the dredge showed a variation of less than 1 NTU. Although Figure 25 seems to show a trend of decreasing turbidity with distance from the dredge, this tendency is not statistically significant. However, statistical analysis of near-surface turbidity data showed significant variation in turbidity values with lateral site location (Appendix Table C-1). Mean turbidity values from sites located in the center of the transects were lower than turbidity values from sites on the east or west. The highest mean near-surface turbidity values were noted on the west site locations (Table 17A).

Similar results were noted in the analysis of turbidity data from near-bottom samples (Table 17A and Appendix Table C-2). Transect distance from the dredging operation had no significant effect on turbidity. A comparison of mean turbidity levels for transects located upstream and downstream showed a variation of less than 1 NTU (Figure 26). Lateral site location significantly affected turbidity values in near-bottom samples. The highest turbidity values were noted on east site locations on all of the transects.

The overall mean value (7.6 NTU) for turbidity in near bottom samples was slightly higher than mean turbidity value in near-surface samples (7.4).

Statistical analysis of suspended solids data for phase I near-surface and near-bottom samples showed a pattern similar to the results for turbidity. In both near-surface and near-bottom samples, no significant trend was evident for suspended solids based on distance upstream or downstream of the dredge (Appendix Tables C-3 and C-4). The overall mean suspended solids values from each of the transects varied by less than 3 mg/l in near-surface samples and by 6 mg/l in near-bottom samples (Figures 27 and 28).

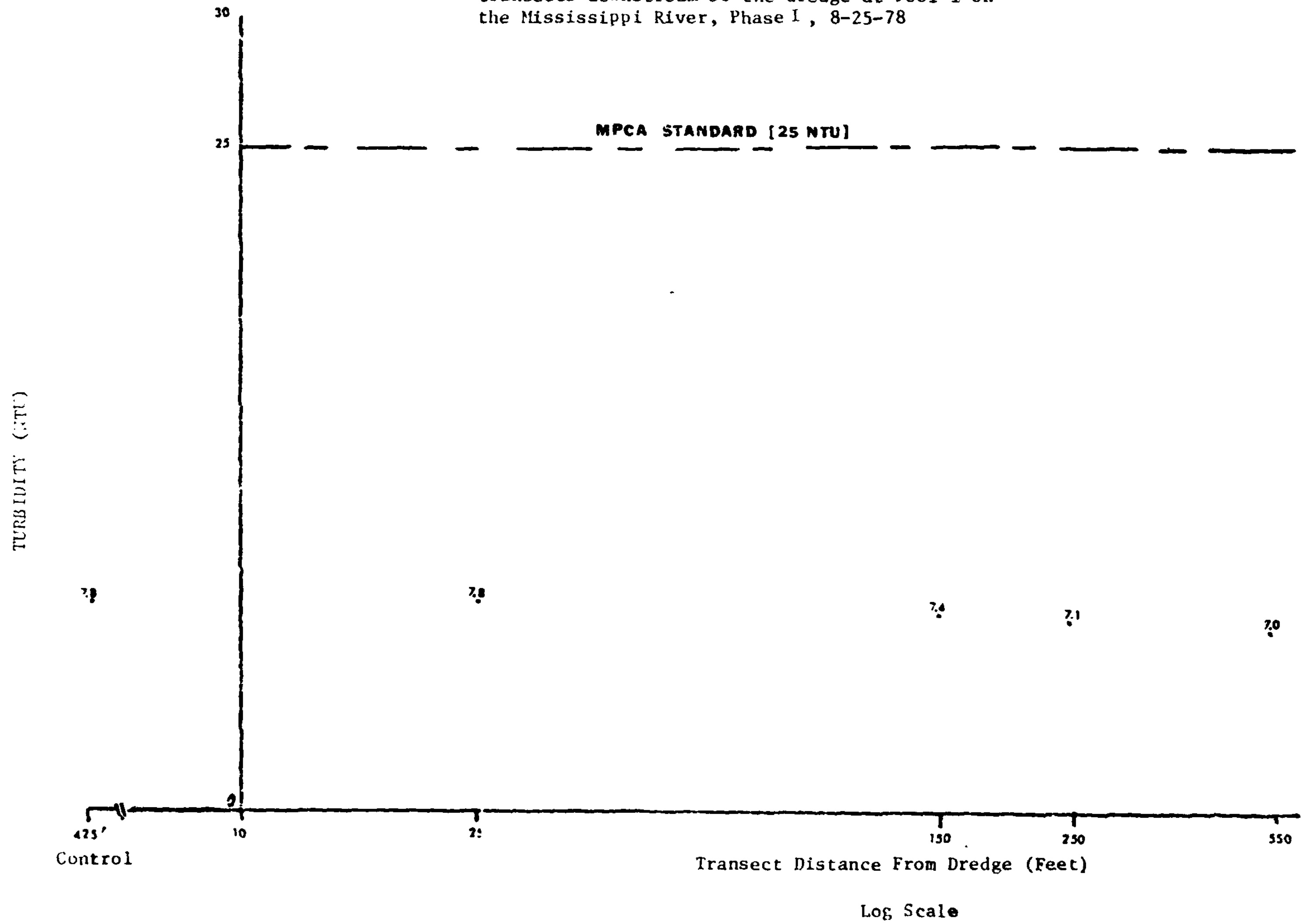
Unlike the turbidity data, site location was significant only for near-surface suspended solids values (Appendix Table C-3). Examination of Table 17B shows that with one exception, near-surface suspended solids values were lowest at the center site location. Near-bottom suspended solids values were not significantly affected by site location on the transect (Appendix Table C-4).

The overall mean value for suspended solids was higher in bottom samples (27.6) than in surface samples (19.5).

Phase II. In phase II, analysis of variance (ANOVA) was conducted on turbidity and suspended solids data collected at two depths from sites on two radials which were oriented downstream of the dredge. The variables analyzed were the distance from the dredge (i.e., transects 50, 100, 200, 300, 700, and 1,225 feet downstream of the dredge) and the radial (i.e., east or west) sampled.

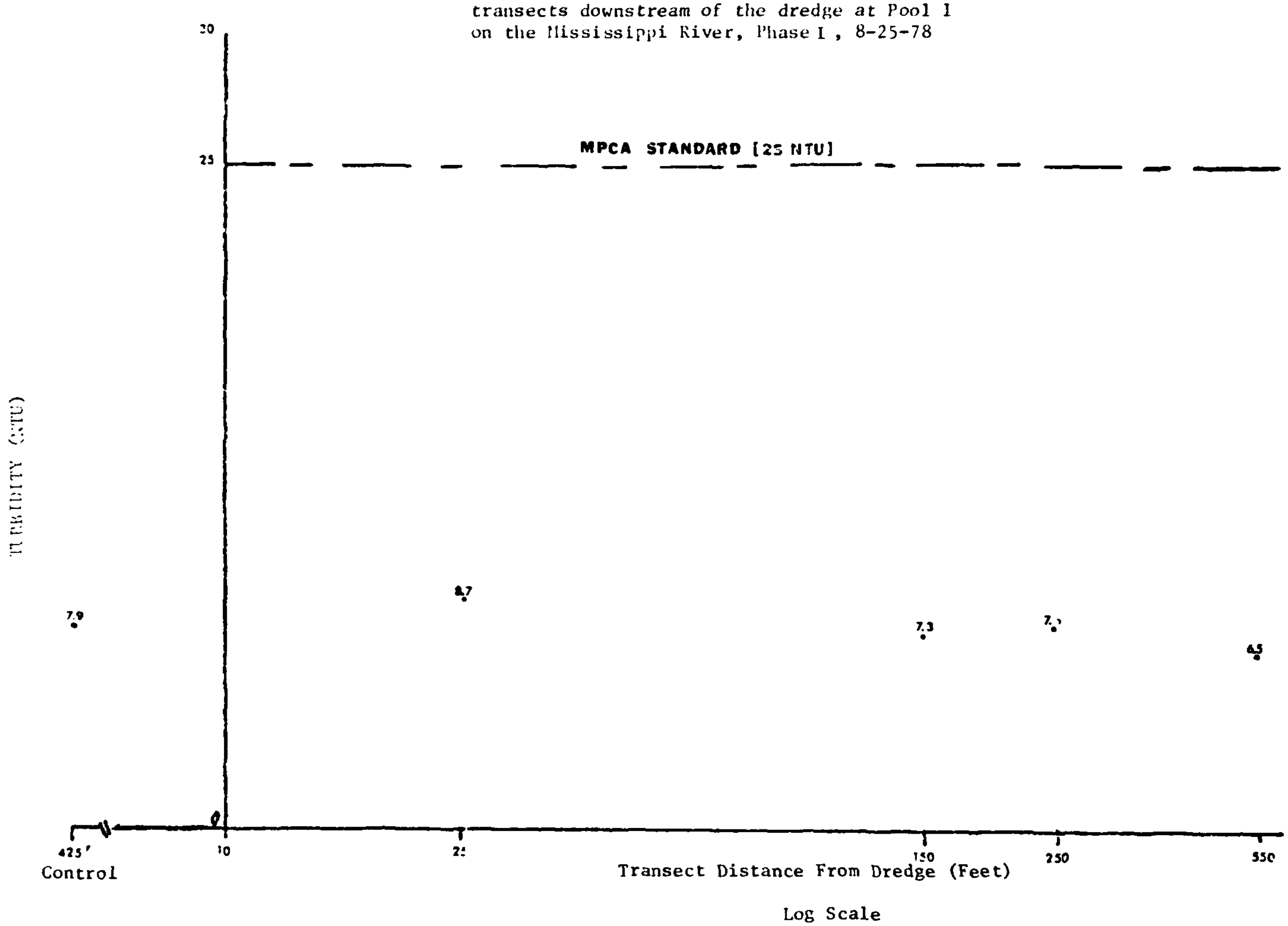
Analysis of turbidity data for surface and bottom samples showed no significant trend with distance downstream (Appendix Table C-5 and C-6 plus Table 18). Similarly, radial location had no effect on turbidity levels. Mean turbidity values downstream of the dredge varied by less than 1 NTU in both near-surface and near-bottom samples (Figures 29 and 30).

FIGURE 25 Mean* near-surface turbidity values (NTU) for transects downstream of the dredge at Pool 1 on the Mississippi River, Phase I, 8-25-78



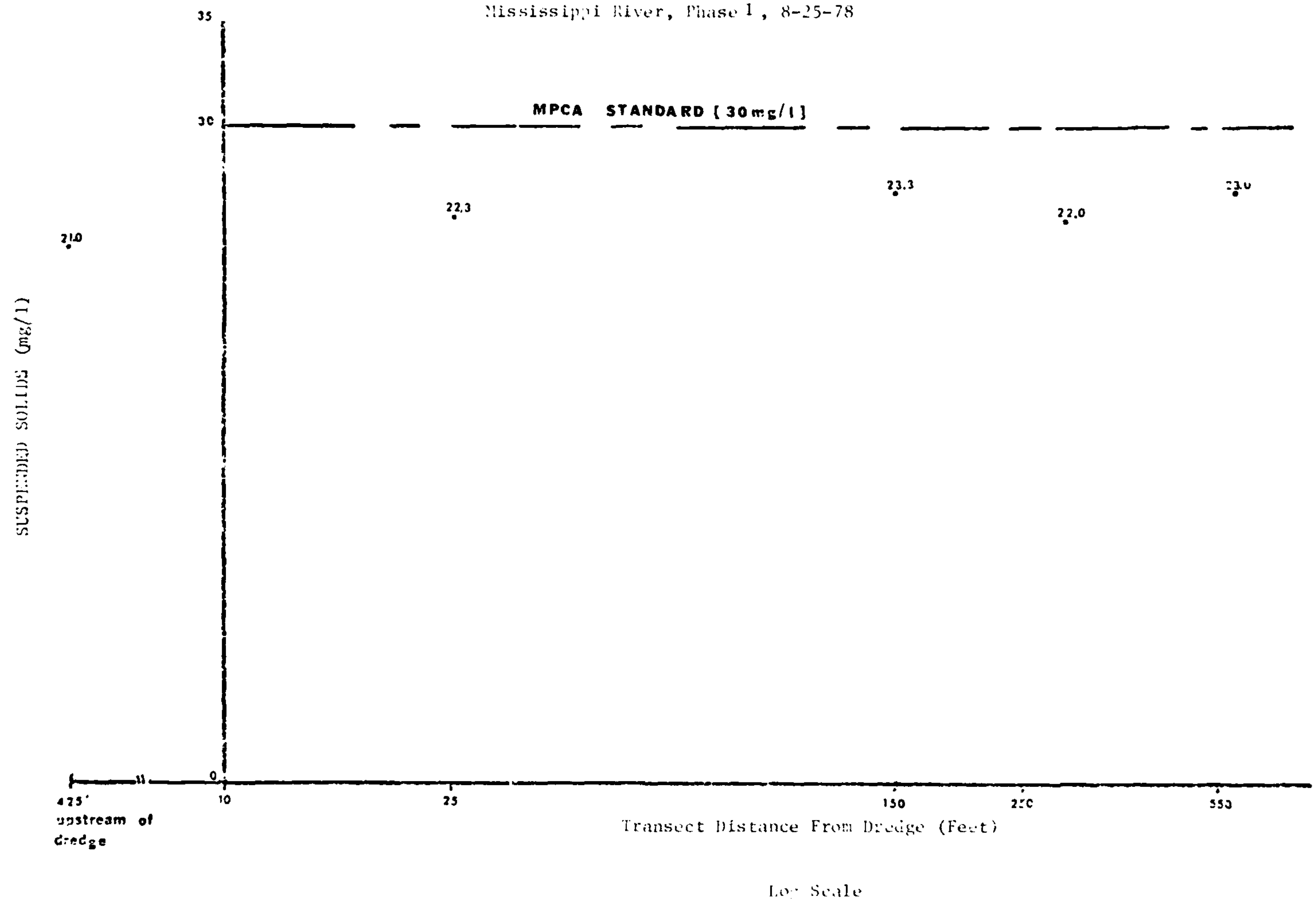
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 26 Mean* near-bottom turbidity values (NTU) for transects downstream of the dredge at Pool 1 on the Mississippi River, Phase I, 8-25-78



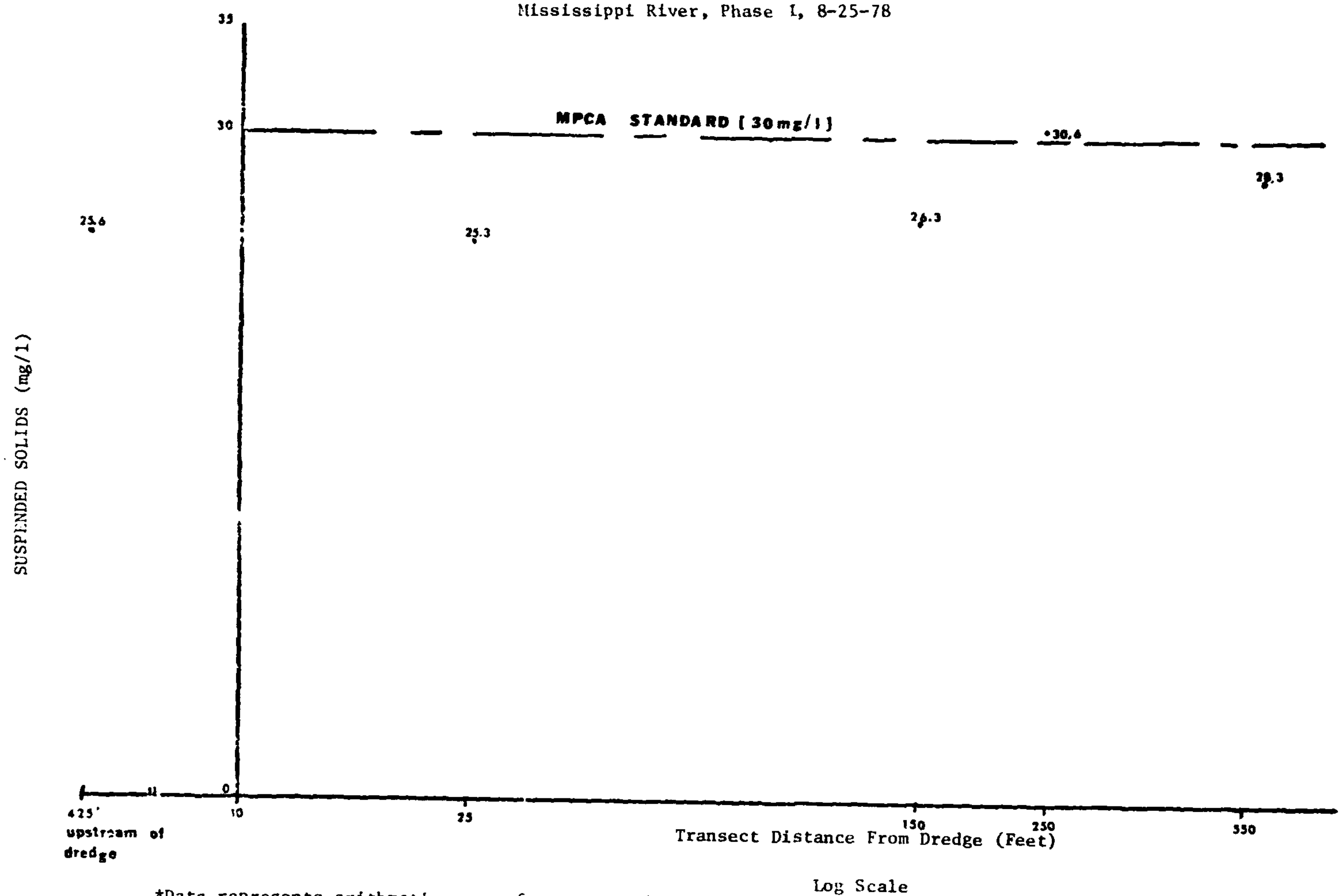
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 27 Mean* near-surface suspended solids values (mg/l) for transects downstream of the dredge at Pool 1 on the Mississippi River, Phase I, 8-25-78



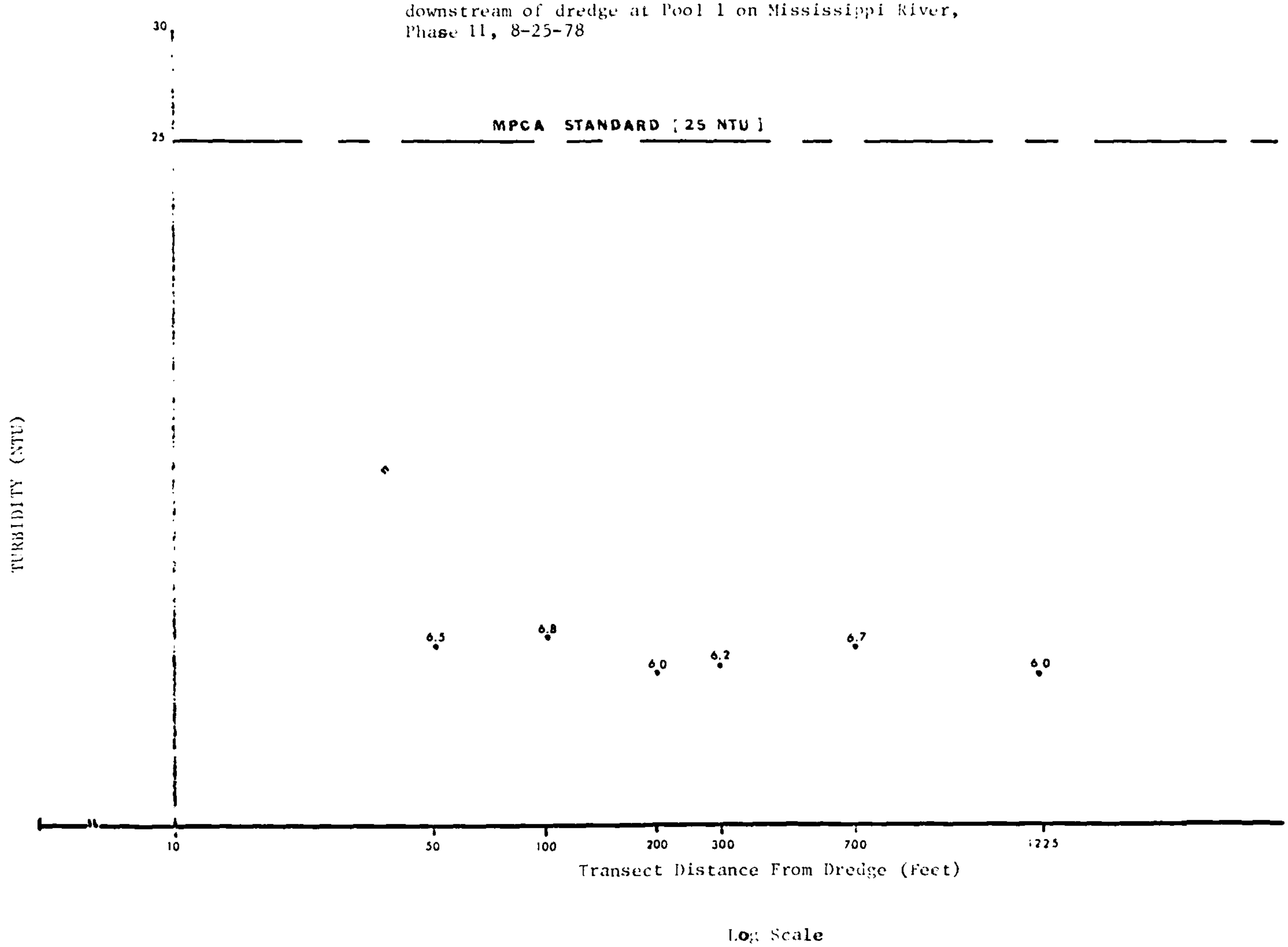
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 28 Mean* near-bottom suspended solids values (mg/l) for transects downstream of the dredge at Pool 1 on the Mississippi River, Phase I, 8-25-78



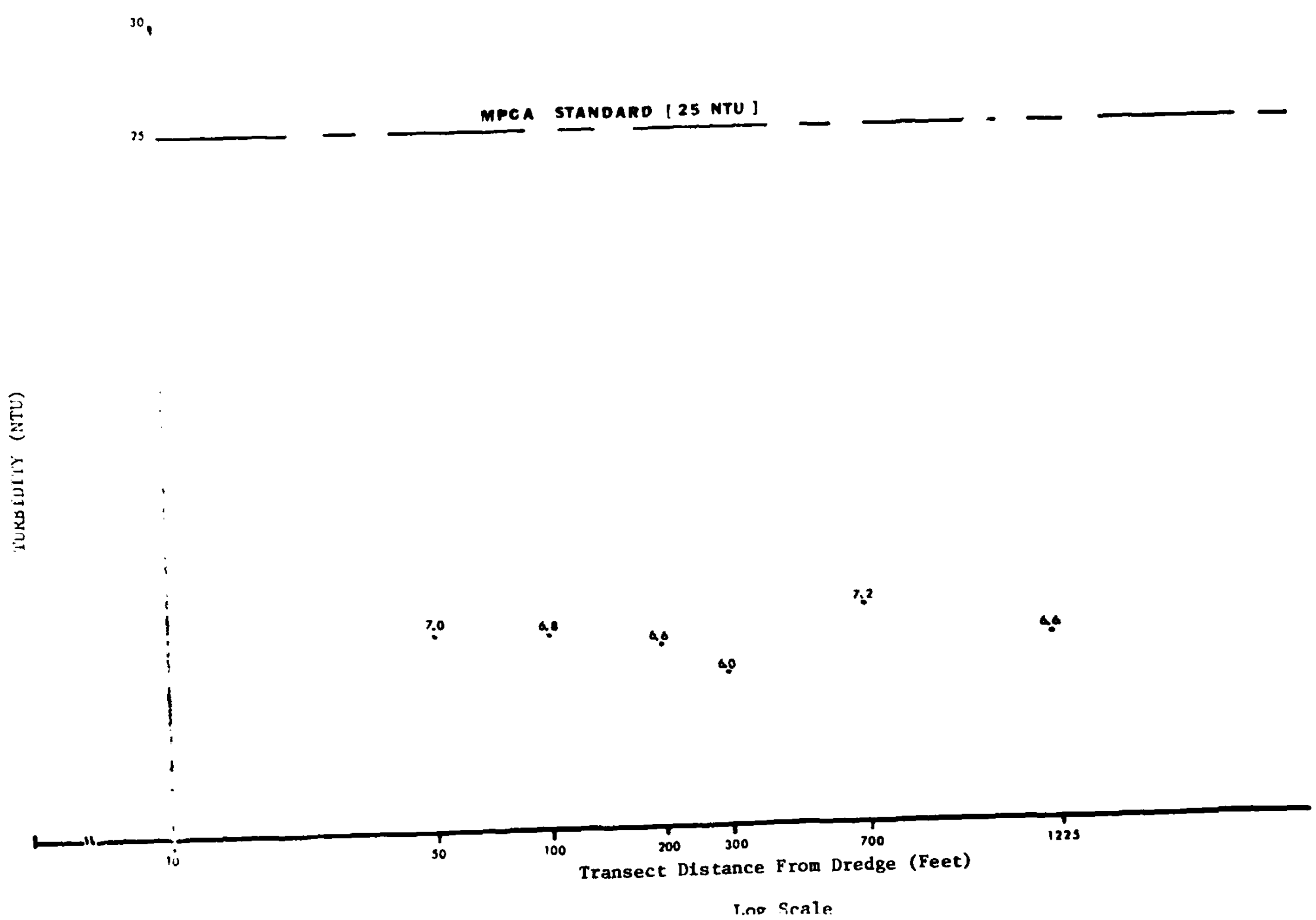
*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 29 Mean* near-surface turbidity values (NTU) for distance downstream of dredge at Pool 1 on Mississippi River, Phase II, 8-25-78



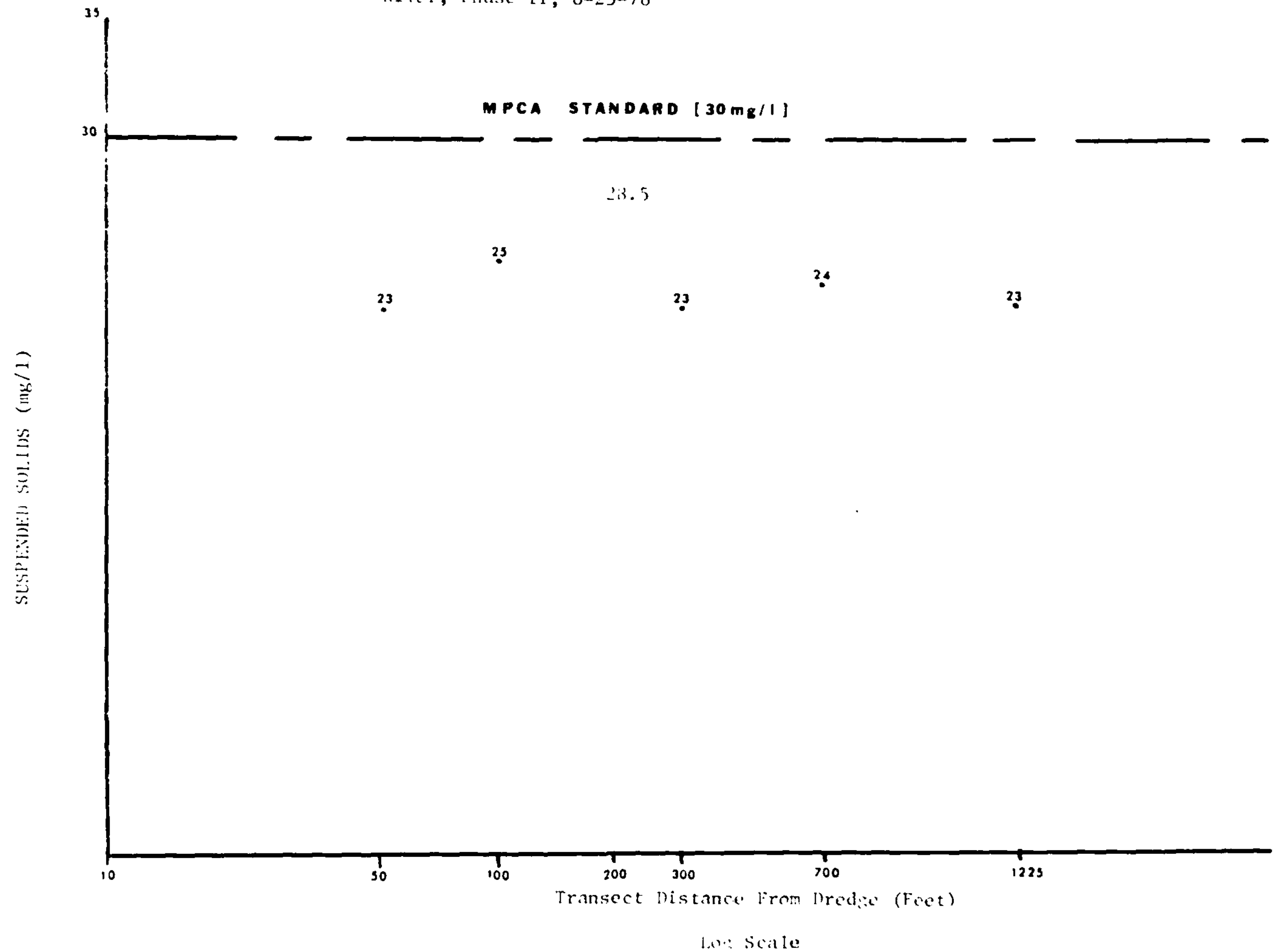
*Data represents arithmetic mean of water samples collected from two sites.

FIGURE 30 Mean* near-bottom turbidity values (NTU) for distance downstream of dredge at Pool 1 on Mississippi River, Phase II, 8-25-78



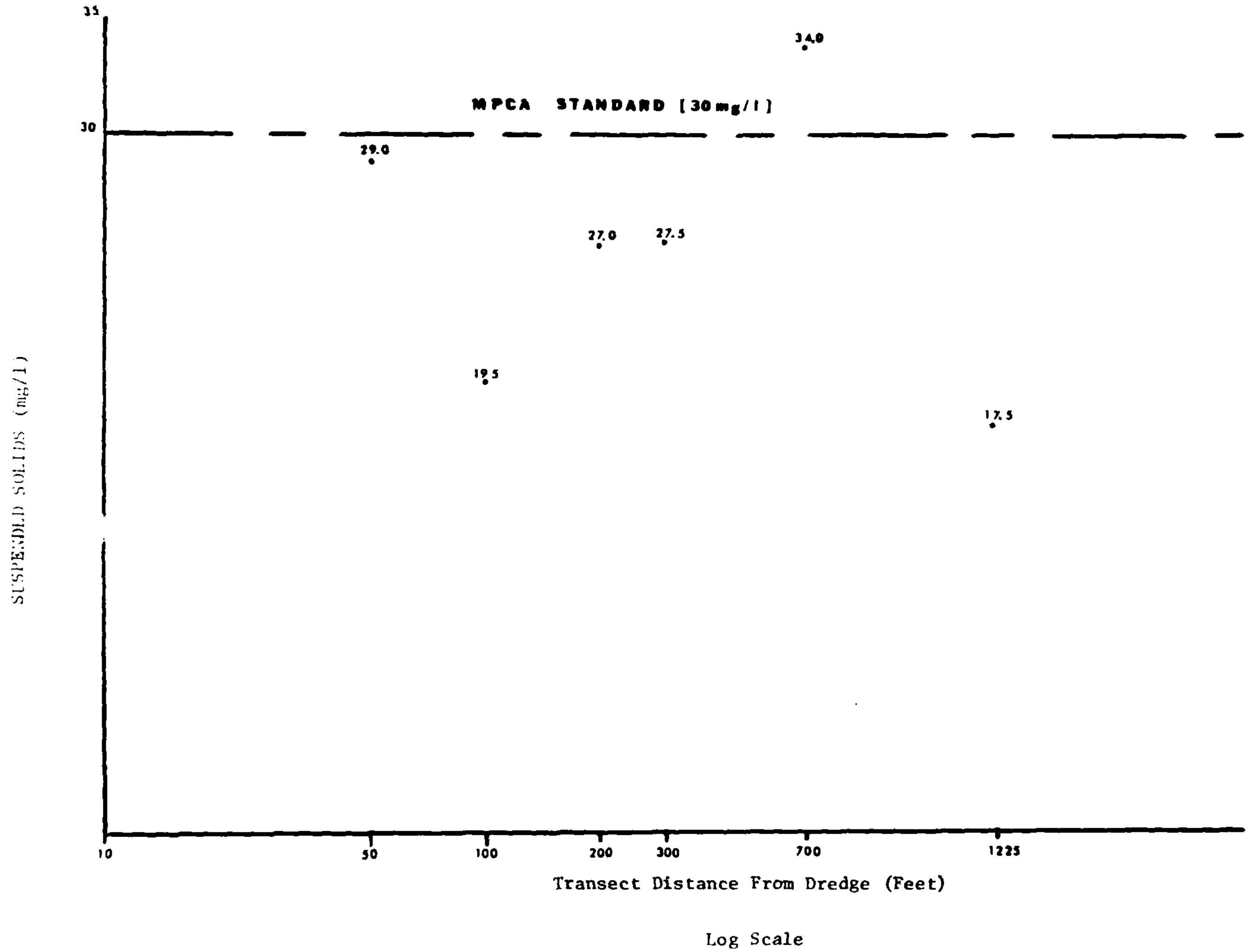
*Data represents arithmetic mean of water samples collected from two sites.

FIGURE 31 Mean* near-surface suspended solids values (mg/1) for distance downstream of dredge at Pool 1 on Mississippi River, Phase II, 8-23-78



*Data represents arithmetic mean of water samples collected from two sites.

FIGURE 32 Mean* near-bottom suspended solids values (mg/1) for distance downstream of dredge at Pool 1 on Mississippi River, Phase II, 8-25-78



*Data represents arithmetic mean of water samples collected from two sites.

As in phase I, phase II turbidity data were also slightly higher in near-bottom samples (6.9 NTU) than in near-surface samples (6.4 NTU) located downstream of the dredge (Table 18A).

Analysis of suspended solids data for phase II near-bottom and near-surface samples showed no trends with distance downstream from the dredge (Figures 31 and 32). Mean suspended solids values ranged from 23 to 28.5 (Figure 31) mg/l in near-surface samples and 17.5 to 34 mg/l (Figure 32) in near-bottom samples. Radial location had no effect on suspended solids in either near-surface or near-bottom samples. As in phase I, elevations of mean suspended solids values were slightly higher in near-bottom samples than mean near-surface samples (25.75 mg/l and 24.25 mg/l, respectively, Table 21).

<u>Phase III</u>. In phase III, turbidity and suspended solids samples were collected over time and from two depths at locations upstream and at points 25 and 250 feet downstream of the dredge after dredging had stopped. Analysis of turbidity and suspended solids data in both near-bottom and near-surface samples indicated no trend or decay related to increasing time after dredging (Table 19). By the time the sampling for the time duration had begun (40 minutes after dredging stopped), the effects of dredging on turbidity and suspended solids seemed to be no longer detectable.

A comparison between means for near-surface and near-bottom samples collected over time at at these locations and means for surface and bottom samples from phase I and phase II (Table 20) shows that turbidity values were not significantly higher during dredging than after dredging.

TABLE 20 Comparison of Mean Turbidity Values (NTU) from Samples Collected Downstream of Dredge During Dredging to After Dredging in Pool 1

	Depth	
	Near-surface	Near-bottom
During Dredging	7.0	7.15
After Dredging	7.7	9.0

Generally, mean concentrations for turbidity values, whether upstream or downstream of the dredge, or collected before or after dredging, fluctuated no more than 1 to 2 NTU.

A comparison of means for near-surface and near-bottom samples collected over time to means from phases I and II shows that suspended solids values were slightly higher (7 to 9 mg/l) during dredging than after dredging (Table 21).

TABLE 21 Comparison of Mean Suspended Solids Values (mg/l) from Samples Collected Downstream of the Dredge During Dredging to After Dredging in Pool 1

	Depth	
	Near-surface	Near-bottom
During Dredging	23.45	26.47
After Dredging	14.6	19.6

SUMMARY OF FINDINGS

1. Particle size analysis indicated that sediments were principally composed of coarse and medium sand-sized particles. A small percentage of clay was also present.

2. Turbidity values in water samples collected during dredging (phases I and II) and after dredging (phase III) were well below MPCA standards for turbidity (25 NTU).

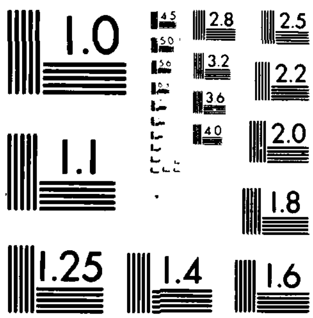
3. Suspended solids values in water samples collected after dredging (phase III) were below MPCA standards (30 mg/l). Values in excess of this standard occurred in 11 cases during phases I and II, and range from 31 to 39 mg/l.

4. The low turbidity and suspended solids values detected in water samples are most likely related to the presence of coarse sand-sized particles in the dredge cut.

AD-A109 984 CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT F/G 13/2
AN ASSESSMENT OF WATER QUALITY IMPACTS OF MAINTENANCE DREDGING --ETC(U)
JAN 81 D D ANDERSON, R J WHITING, B JACKSON

UNCLASSIFIED NL

2 of 3
AD
A109984



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

5. Turbidity and suspended solids values did not show any trends with distance from the dredge. According to statistical analysis of phase I and II, the study indicated that the dredge was not acting as a point source for increased levels of turbidity or suspended solids. The levels of turbidity and suspended solids detected downstream of the dredge were not significantly different from levels detected upstream of the dredge.

6. In Phase I, lateral site location on each transect did affect the level of turbidity in near-surface and near-bottom samples collected during dredging. Site location also had a significant effect on near surface suspended solids values.

In general, turbidity values were lowest in the center of each transect.

Similarly, suspended solids values were lowest at center sites in near-surface samples. Site location on a transect did not have a significant effect on near-bottom suspended solids values.

7. Lateral site location on each radial did not significantly affect the level of turbidity or suspended solids in phase II of the study. These results may have been due to the close position of the two radials to mid-river.

8. The level of turbidity and suspended solids was slightly higher in near-bottom samples than near-surface samples in both phase I and phase II. In addition, phase I overall bottom turbidity levels were higher than those in phase II. The higher levels noted in phase I are indicative of the higher levels detected on east location sites.

9. Forty minutes after dredging, turbidity and suspended solids values did not show any decay curve trends.

10. Mean turbidity values during dredging were not significantly higher than after dredging.

11. Mean suspended solids values during dredging were 7 mg/l higher than after dredging.

CONCLUSIONS

Although suspended solids values were higher (7 mg/l) during dredging than after dredging, clamshell dredging operations had a minimal effect on water quality in Pool 1 of the Mississippi River. No significant changes or trends in suspended solids values were noted with transect distance either upstream or downstream of the dredge. Fluctuations in suspended solids values were not significant. Suspended solids values were for the most part below MPCA standards.

Similarly, no significant changes in turbidity values were detected with distance from the dredge, nor were any significant trends in turbidity values in samples collected over time after dredging. A comparison of mean turbidity values during and after dredging with distance downstream of the dredge shows a variation of 1-2 NTU. Turbidity values were uniformly low and well below MPCA standards.

In contrast, significant differences in turbidity and suspended solids values (with one exception -- suspended solids values near bottom), were noted with sample site location on each of the transects in phase I of the study. This result, however, is most probably due to the hydrological features of this reach of the river rather than a result of dredging.

At this dredge site, it would appear that a clamshell dredging operation does not act as a major point source for increased levels of turbidity or suspended solids.

HEAD OF LAKE PEPIN (RIVER MILE 784.6) - MONITORING OF TURBIDITY AND SUSPENDED SOLIDS CHANGES RESULTING FROM CLAMSHELL DREDGING OPERATIONS (HAUSER)

OBJECTIVE

The objective of this study was to assess the areal extent and time duration of turbidity and suspended solids changes resulting from a clamshell dredging operation at the Head of Lake Pepin (Wacouta Point - river mile 784.6).

METHODS

DESCRIPTION OF SAMPLING SITE

Wacouta Point, river mile 784.6, is located at the Head of Lake Pepin on the Upper Mississippi River. Although this area has required dredging only twice since 1956, the amount of material dredged on those two occasions was quite extensive: 105,000 and 400,000 cubic yards. The lack of an appropriate disposal site makes disposing of dredge material on land in this area difficult.

During the 1978 maintenance dredging season, a test was conducted at the Head of Lake Pepin to see if clamshell dredging was a feasible dredging method for the fine material present at this site. The dredge HAUSER operated for only 1 day on 2 November 1978. Dredged material was disposed of on land in the Bay Point Park area of the city of Red Wing Minnesota.

EXPERIMENTAL DESIGN

Sediment. Six sediment samples were collected within the area to be dredged by a modified Ponar bottom sediment sampler coated with a nonmetallic paint. The samples were analyzed for bulk chemical constituents by the U.S. Geological Survey Laboratory in Atlanta, Georgia. In addition, three of the sediment samples were analyzed for total particle size by Aqua-Tech, Inc., Port Washington, Wisconsin, and three by Missouri River Division (MRD) Soils Laboratory, Omaha, Nebraska. MRD also conducted settleability tests on the three sediment samples.

Current Velocity. Prior to the water sampling on 2 November 1978, data on the magnitude of the water currents were collected with a pygmy current meter. Measurements were taken at three sites near the dredge at two depths, 1 foot from the surface and 1 foot from the bottom.

Areal Extent. This part of the study consisted of two sampling phases. The first phase consisted of taking water samples along four transects, at locations 20, 60, 320, and 1,280 feet downstream from the dredge and at one control site located upstream from the dredging operation (refer to Figure 33). On each of the transects three sampling sites were positioned. Along a transect, discrete water samples were collected simultaneously at the three sampling sites and at two depths, 1 foot from the surface and 1 foot from the bottom. When one transect was completed, another was started as soon after as possible. This phase resulted in the collection of 26 water samples for analysis of turbidity and suspended solids.

The second sampling pnase consisted of collecting water samples at mid-depth along two transects radiating from the dredge in a downstream direction (refer to Figure 34). Sampling sites were positioned along each of these radial transects at geometrically decreasing distances from the dredge, starting at 1,550 feet and ending at 10 feet from the dredging, for a total of eight sampling sites on each transect. Water samples were collected simultaneously along the two transects at equal distances downstream of the dredge. This sampling plan resulted in the collection of 16 additional water samples for turbidity and suspended solids analysis.

Time Duration. On 2 November 1978, the dredge stopped its activity at 1530 hours. Water samples, for turbidity and suspended solids analysis, were collected at two depths for three sites over designated time intervals (¼, ½, 1, 2, and 4 hours) after the dredge had stopped operation. The three sampling sites that were sampled during the time duration study included the control site, and at one of the sites on each of the 20- and 320-foot transects (refer to Figure 33). The samples were not taken simultaneously at the three sites, but there was a precise recording of time and the sequence of sampling the sites was consistent.

RESULTS

FIELD CONDITIONS

Weather conditions on 2 November 1978 were sunny with low winds. Air temperature ranged from 50°F to upper 60s°F during the sampling. Current velocities were higher near the surface than the bottom, having a mean velocity of 1.18 ft/second one foot below the surface to 1.03 feet/second one foot above the bottom.

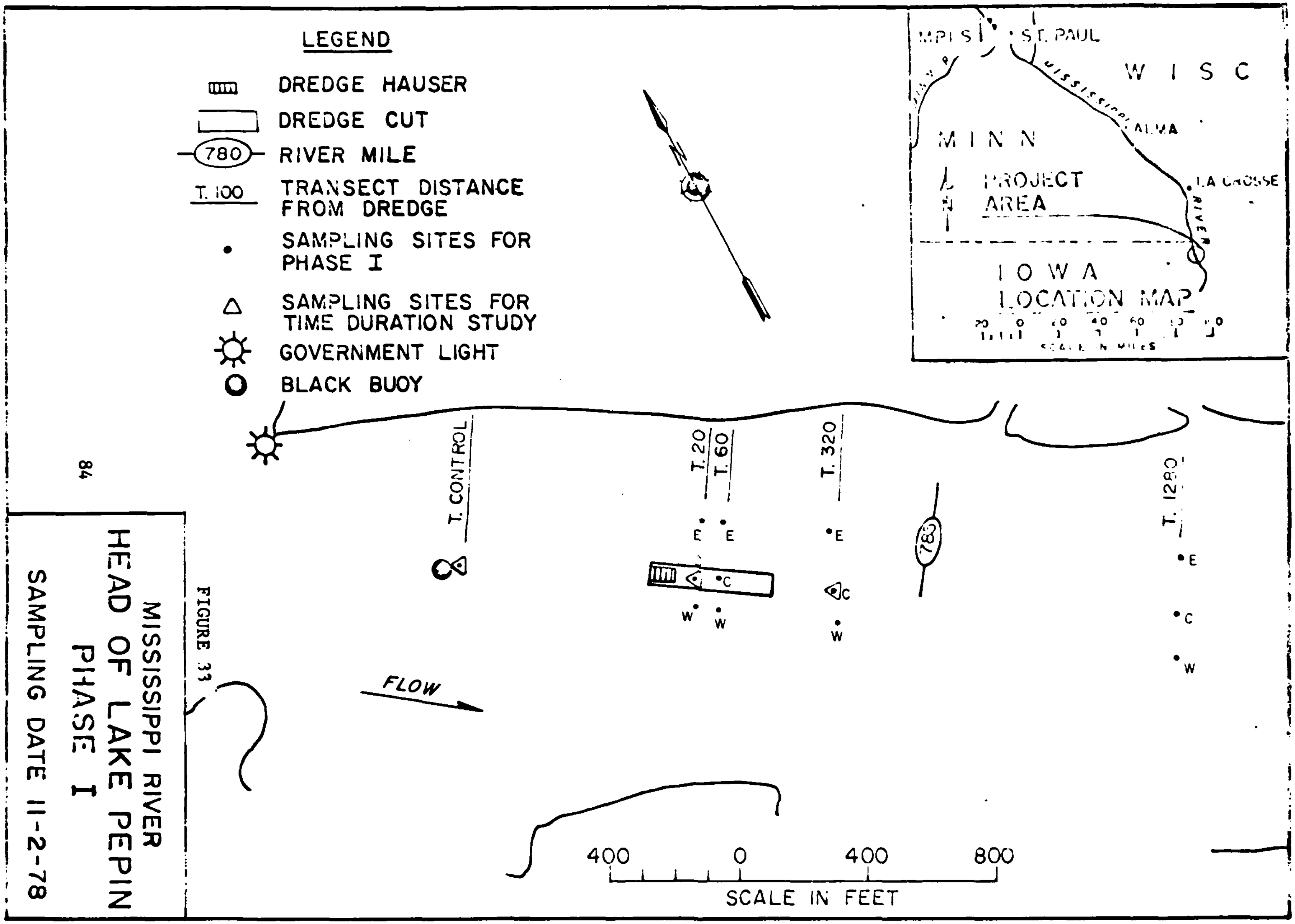


FIGURE 33

MISSISSIPPI RIVER
HEAD OF LAKE PEPIN
PHASE I
SAMPLING DATE 11-2-78

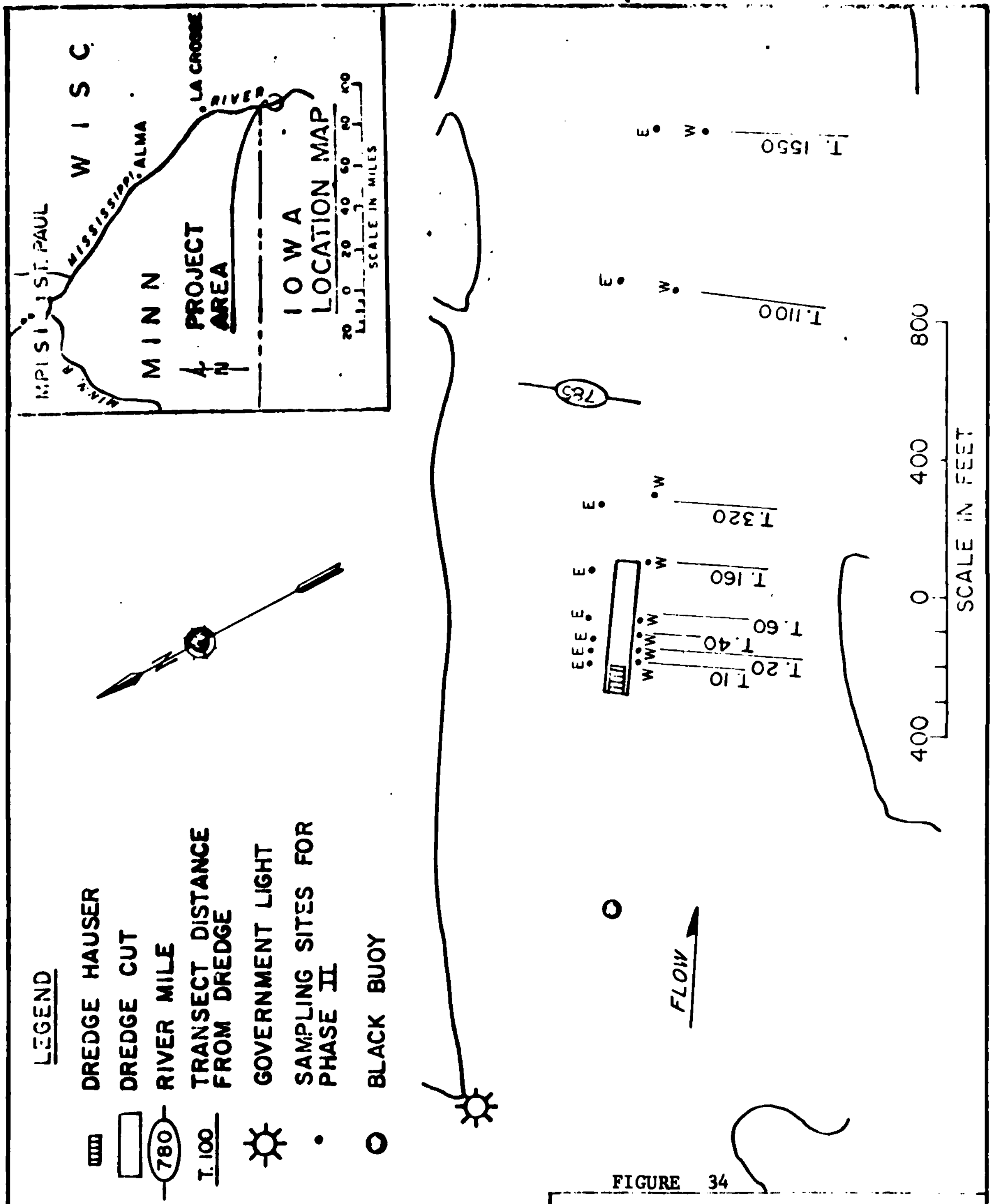


FIGURE 34

MISSISSIPPI RIVER
HEAD OF LAKE PEPIN
PHASE II

SAMPLING DATE 11-2-73

SEDIMENT

Particle Size. Particle size analysis indicated that the sediments from the dredge cut consisted mainly of coarse- to medium-grain sand, with a mean percent composition of the two grain sizes of 82.37 percent (Table 22). Fines (clays and silts) had a mean percent composition of 8.30, with clays more abundant than silts.

The amount of fine material (clays and silts) at the head of Lake Pepin is greater than that at many other dredge cut areas surveyed by the Army Corps of Engineers in 1974 (GREAT I WQWG - 1979). However, it has considerably less fine material than that reported for the rest of Lake Pepin (GREAT I SECWG, unpublished; McHenry, Ritchie, and Cooper, 1977).

TABLE 22 Percent Composition of Particle Sizes of Sediments Collected from the Head of Lake Pepin Dredge Cut on 11/2/78 (Analysis Conducted by Aqua-Tech, Inc., Port Washington, Wisconsin.).

	Sampling Code		
Classification	ALP-1	ALP-2	ALP-3
>sand	1.28	0.74	0.07
coarse sand	19.08	24.26	10.36
medium sand	65.15	57.86	70.47
fine sand	6.90	9.45	9.48
silt	2.80	2.83	4.81
clay	4.79	4.86	4.81
Percent Summation	100.00	100.00	100.00

Bulk Chemical Constituents. Bulk chemical analysis of six sediment samples from the Head of Lake Pepin indicated low concentrations of metals and nutrients (Table 23). The values for most of the metals and nutrients are generally comparable to those reported below Pool 2 on the Upper Mississippi River, excluding Lake Pepin, from another study (GREAT I WQWG, 1978). Lead, total

Kjeldahl nitrogen, and residue after loss on ignition (Res. LOI) are the only parameters that showed slight elevations over those reported for sediments below Lake Pepin. However, even those three parameters are considerably below the values reported for Lake Pepin and for areas in and above Pool 2.

Pesticides were below the limits of detection in all of the sediment samples. PCB's were detected in all of the sediment samples in the 1 to 2 ug/kg range. These values are considerably lower than those reported in another Lake Pepin study (PCB Interagency Task Force, 1976). In general, the dredge cut sediments were fairly clean, although it should be noted that the sediments were collected from the upper to middle portion of the historical dredge cut and may not be totally reflective of the lower portion.

TURBIDITY AND SUSPENDED SOLIDS

Phase I. In sampling phase I, turbidity downstream of the dredge ranged from 11.7 to 16.0 NTU 1 foot below the surface. Turbidity values 1 foot above the bottom downstream of the dredge ranged from 11.7 to 21.8 NTU. A control sample taken upstream of the dredge yielded readings of 13.3 NTU near the surface and 12.7 NTU near the bottom (Table 24A).

Suspended solids downstream of the dredge ranged from 23 to 35 mg/l near the surface and from 25 to 58 mg/l near the bottom. The control had suspended solids values of 24 mg/l near the surface and 52 mg/l near the bottom (Table 24B).

No turbidity values in excess of MPCA standards of 25 NTU were noted for either the control sample or the samples downstream of the dredge. Suspended solids values near the surface were in excess of MPCA standards in 4 out of 12 samples collected downstream of the dredge. Suspended solids values in excess of MPCA standards of 30 mg/l were also noted in the control sample near the bottom and in all but one of the near-bottom samples located downstream of the dredge.

TABLE 23 Bulk Chemical Data of Sediments Collected from the Head of Lake Pepin Dredge Cut on 11/2/78 (Analyses Conducted by U.S. Geological Survey Laboratory, Atlanta, Georgia).

	Site					
Parameter (ug/kg)	ALP-1	ALP-2	ALP-3	ALP-4	ALP-5	ALP-6
Arsenic	0	0	0	0	0	0
Barium	0	0	0	0	0	0
Cadmium	<10	<10	<10	<10	<10	<10
Chromium (Total)	<10	<10	<10	<10	<10	<10
COD	6600	1100	2300	940	3700	2100
Copper	<10	<10	<10	<10	<10	<10
Cyanide	0	0	0	0	0	0
Iron	2100	2400	2600	1800	1900	2300
Lead	20	20	20	20	20	10
Manganese	130	130	120	80	100	140
Mercury	0.00	0.00	0.00	0.00	0.00	0.00
N KJD	320	280	380	220	370	410
N, NH_4 as N	2.3	1.3	2.1	1.7	1.5	1.2
Nickel	<10	<10	<10	<10	<10	<10
Oil and grease	0	0	0	0	0	0
Phos. Tot.	110	84	170	240	240	130
Res. LOI.	3400	3500	5760	2990	3000	4130
Zinc	<10	20	10	<10	<10	10
Pesticides ug/kg						
Aldrin	0.0	0.0	0.0	0.0	0.0	0.0
Chlordane	0	0	0	0	0	0
DDD	0.0	0.0	0.0	0.0	0.0	0.0
DDE	0.0	0.0	0.0	0.0	0.0	0.0
DDT	0.0	0.0	0.0	0.0	0.0	0.0
Dieldrin	0.0	0.0	0.0	0.0	0.0	0.0
Endosulfin	0.0	0.0	0.0	0.0	0.0	0.0
Endrin	0.0	0.0	0.0	0.0	0.0	0.0
Hept. Epox.	0.0	0.0	0.0	0.0	0.0	0.0
Heptachlor	0.0	0.0	0.0	0.0	0.0	0.0
Lindane	0.0	0.0	0.0	0.0	0.0	0.0
Mirex	0.0	0.0	0.0	0.0	0.0	0.0
PCB	1	1	2	2	1	2
PCN	0	0	0	0	0	0
Perthane	0.0	0.0	0.0	0.0	0.0	0.0
Toxaphene	0	0	0	0	0	0

TABLE 24 Head of Lake Pepin Dredge Site (11/2/78). Sampling Phase I: Comparison of Turbidity and Suspended Solids With Depth and Distance Downstream of the Dredge. (Analyses Performed by Aqua-Tech, Inc., Port Washington, Wisconsin.)

TABLE 24A Turbidity (NTU)

		Surface			Bottom		
Transect		E	C	W	E	C	W
	Control		13.3			12.7	
Distance from dredge (feet)	20	12.7	13.0	12.3	13.7	16.0	12.2
	60	12.7	16.0	11.7	13.3	17.0	12.8
	320	13.3	12.0	13.3	13.0	12.7	13.7
	1280	12.3	13.7	12.3	14.3	11.7	21.8

TABLE 24B Suspended Solids (mg/l)

		Surface			Bottom		
Transect		E	C	W	E	C	W
	Control		24			52	
Distance from dredge (feet)	20	28	32	24	58	49	30
	60	28	32	24	45	50	25
	320	29	35	24	46	44	35
	1280	28	32	23	47	43	135*

*Deemed to be an outlier and not included in any of the Statistical Analyses.

Phase II. Sampling phase II consisted of taking samples at mid-depth along two transects radiating downstream of the dredge (Figure 34). Turbidity and suspended solids values ranged from 13.5 to 20.0 NTU and 16 to 42 mg/l, respectively (Table 25).

Turbidity values were below MPCA standards of 25 NTU in all samples collected during this phase (Table 25A). Suspended solids values in excess of MPCA standards of 30 mg/l extended 640 feet downstream of the dredge along one of the radiating transects. The other radiating transects did not show any values above MPCA standards (Table 25B).

Phase III. Water samples were collected over designated time intervals after dredging had stopped in the area. The samples collected after dredging had turbidity values ranging from 8.1 to 13.7 NTU near the surface and 10.7 to 16.5 NTU near the bottom (Table 26A). Suspended solids values ranged from 21 to 30 mg/l near the surface and 34 to 82 mg/l near the bottom (Table 26B).

As was also noted for the samples taken during dredging, no turbidity values were in excess of MPCA standards for any of the samples collected during the time duration study. Suspended solids were found above MPCA standards in only one near-surface sample. Near the bottom, suspended solids were in excess of MPCA standards for all samples, both at the control site and the sites downstream of the dredge.

STATISTICAL EVALUATION

Phase I. The phase I turbidity data was analyzed using an analysis of variance to compare distance downstream from the clamshell dredge and lateral sampling site location on a transect (Appendix D). The analysis of variance showed no significant difference in turbidity values with distance downstream of the dredge nor with location within the channel for either the near-surface or near-bottom samples (Appendix Tables D-1 and D-2).
Mean turbidity values for transects located downstream of the dredge fluctuated less than 1 NTU for near-surface and near-bottom samples (Figures 35 and 36).

Pooling all the turbidity data from phase I samples collected downstream of the dredge yields overall means of 12.6 NTU near the surface and 13.7 NTU near the bottom. A control sample taken upstream of the dredge yielded turbidity values of 12.7 NTU near the surface and 13.3 NTU near the bottom (Table 24A).

Like the turbidity data, suspended solids data from phase I were analyzed statistically. The analysis of variance indicated no significant difference with distance downstream of the dredge (Appendix Tables D3 and D4). However, there was a significant difference based on lateral sampling site position on a transect for both near-surface and near-bottom samples. The center sampling site positions showed the highest concentrations. This would indicate that any effects on suspended solids concentrations caused by clamshell dredging were mainly limited to the center of the channel.

TABLE 25 **Head of Lake Pepin Dredge Site (11/2/78). Sampling Phase II: Comparison of Turbidity and Suspended Solids (Mid-depth) With Distance Downstream of the Dredge (Analyses Performed by Aqua-Tech, Inc., Port Washington, Wisconsin).**

TABLE 25A Turbidity (NTU)

Distance from Dredge (Feet)

		10	20	40	60	160	320	640	1280
Radial	RDE	14.2	20.0	15.3	17.3	19.3	16.0	16.5	14.2
Transect	RDW	16.7	ND	16.7	13.7	14.3	16.0	15.8	13.5

TABLE 25B Suspended Solids (mg/1)

Distance from Dredge

		10	20	40	60	160	320	640	1280
Radial	RDE	42	35	35	38	37	34	32	26
Transect	RDW	24	ND	21	22	22	21	21	16

ND = No data.

TABLE 26 Head of Lake Pepin Dredge Site (11/2/78). Sampling Phase III: Comparison of Turbidity and Suspended Solids Over Designated Time Intervals After Dredging at Three Sites and at Two Depths. (Analyses Performed by Aqua-Tech, Inc., Port Washington, Wisconsin.)

TABLE 26A Turbidity (NTU)

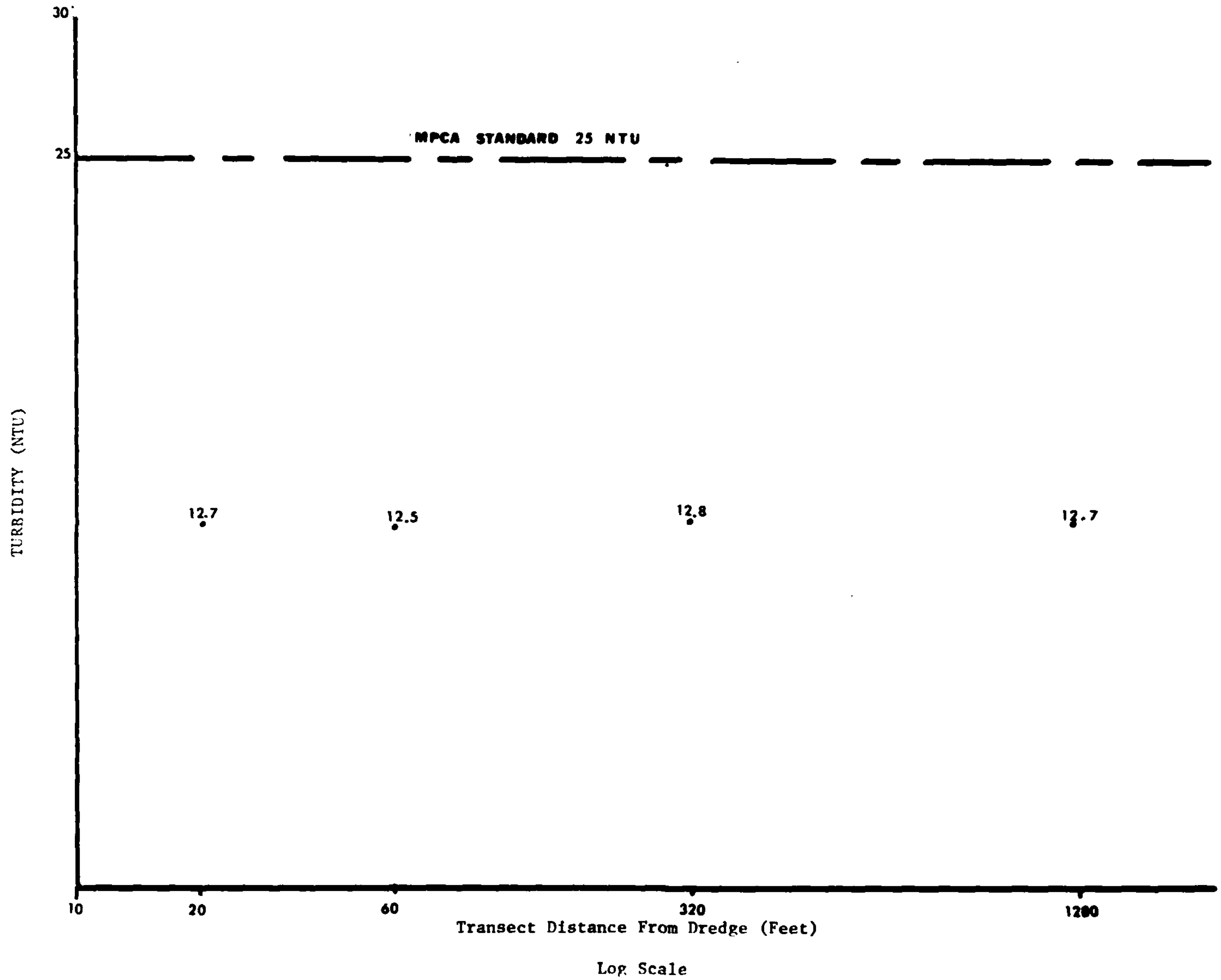
		Surface			Bottom		
Sampling Sites		Control	20 C	320 C	Control	20 C	320 C
	During Dredging	13.3	13.0	12.0	12.7	16.0	12.7
Time[1] After Dredging (hours)	¼	12.0	9.7	13.3	12.8	15.8	12.5
	½	11.7	10.6	11.7	16.2	14.7	13.3
	1	11.3	13.7	12.0	13.7	16.5	11.7
	2	11.3	11.3	11.7	13.7	10.7	13.7
	4	11.3	9.8	8.1	12.8	11.3	12.3

TABLE 26B Suspended Solids (mg/l)

		Surface			Bottom		
Sampling Sites		Control	20 C	320 C	Control	20 C	320 C
	During Dredging	24	32	35	52	49	44
Time[1] After Dredging (hours)	¼	25	23	30	41	42	35
	½	25	24	24	82	38	38
	1	25	23	26	58	34	37
	2	26	24	24	46	33	40
	4	22	22	21	43	35	35

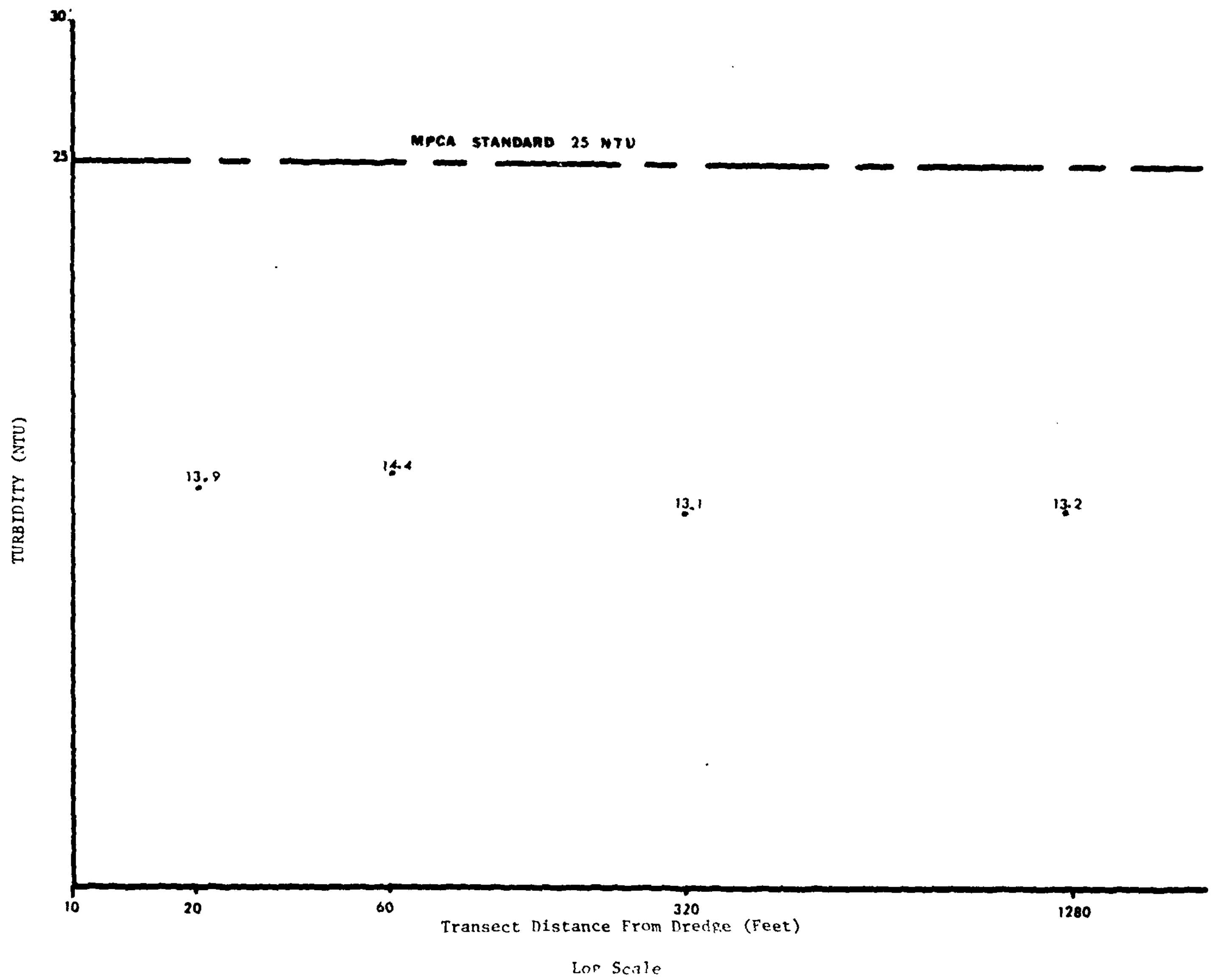
1) Approximate times. See contractor's report in Appendix H for specific times.

FIGURE 35 Mean* near-surface turbidity values (NTU) for transects downstream of dredge at the Head of Lake Pepin, Phase I, 11-2-78



*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 36 Mean* near-bottom turbidity values (NTU) for transects downstream of dredge at the Head of Lake Pepin, Phase I, 11-2-78



*Data represents arithmetic mean of water samples collected from three sites on each transect.

Fluctuations in mean suspended solids concentrations of transects located downstream of the dredge ranged within 2 mg/l near the surface and 7 mg/l near the bottom (Figures 37 and 38). The lowest mean concentration of suspended solids was found in the transect located farthest downstream of the dredge (1280 feet) for both near-surface and near-bottom samples.

Pooling all the suspended solids data from samples collected downstream of the dredge yielded overall means of 28.3 mg/l near the surface and 41.6 mg/l near the bottom. Control samples yielded values of 24 mg/l near the surface and 52 mg/l near the bottom.

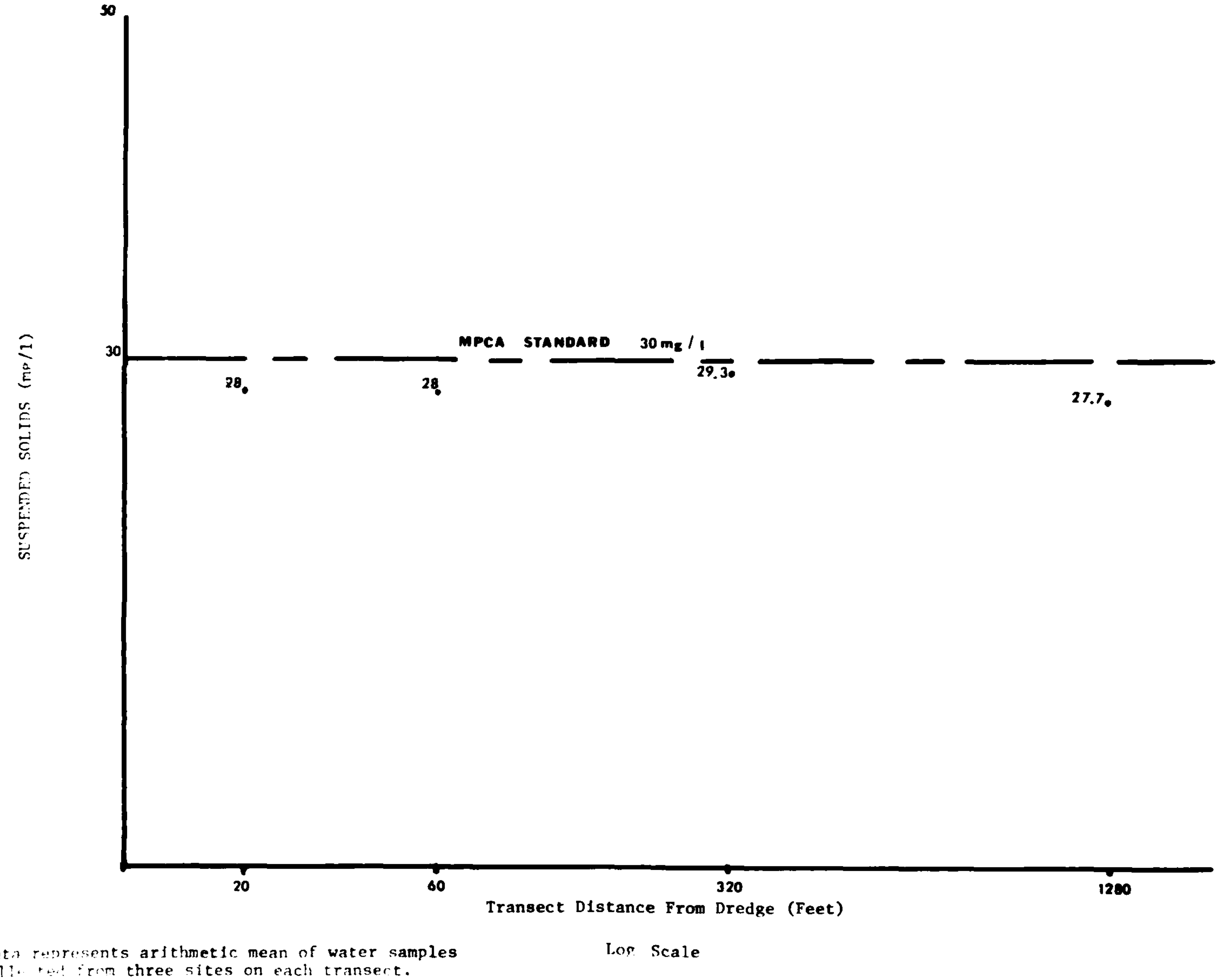
Phase II. In this phase, samples were collected at mid-depth. Turbidity values do not fit an exponential decay curve due to the low values at the 10-foot sampling site (Figure 39). Turbidity concentrations were found to decrease with distance downstream of the dredge, but only by 1 or 2 NTU. A regression analysis comparing turbidity values with distance (on a log scale) below the dredge yields a flat line, indicating no significant trend with distance below the dredge.

Suspended solids values were significantly lower along the west radial than the east radial. Regression analysis of suspended solids versus the log of the distance below the dredge yields non-zero slopes and a decrease in concentrations with distance. However, an exponential decay curve model does not fit the data well (Figure 40). From Figure 40, it would appear that the two radials produce parallel pictures, with the east radial being somewhat higher. Both radials show an initial decrease in suspended solids concentrations within 20 feet of the dredge, a leveling off of values from 20 to 640 feet, and another decrease in values beyond 640 feet downstream of the dredge. One reason that values beyond 640 feet may decrease is that the river enters Lake Pepin at this point and the widening there may result in better dilution.

Phase III. The time duration study was conducted at 3 sites: control, 20-C, and 320-C (refer to Figure 33). Decay curves for turbidity concentrations were noted only at the control site (surface) and site 320-C (surface). (See Figures 41, 42, and 43.) Turbidity concentrations were generally highest in bottom samples, with a mean value of 13.5 NTU, compared with mean value of surface concentrations of 11.4 NTU. These values compare favorably with control means for turbidity in surface and bottom samples of 11.5 NTU and 13.7 NTU, respectively. All samples at all sites were well within MPCA standards for turbidity (25 NTU).

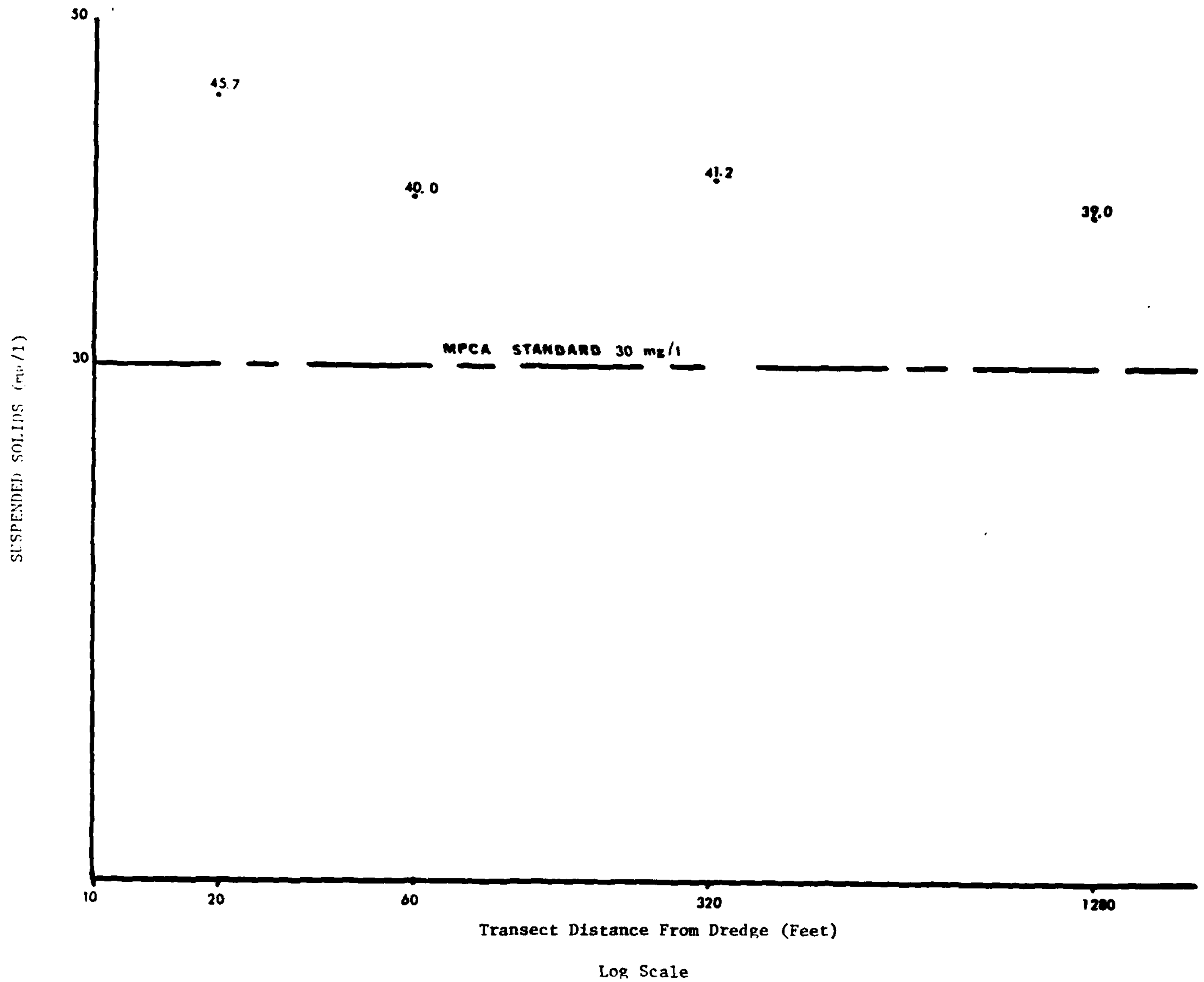
Concentration of suspended solids showed similarly poor trends with time (Figures 44, 45, and 46). The control site showed the highest single concentration of suspended solids, 82 mg/l, a value nearly twice as great as the highest single value (42 mg/l) found below the dredge site at station 20-C, 19 minutes after dredging (Table 26B). All suspended solids concentrations taken 1 foot below the surface were within MPCA standards for this parameter

FIGURE 37 Mean* near-surface suspended solids values (mg/1) for transects downstream of dredge at the Head of Lake Pepin, Phase I, 11-2-78



*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 38 Mean* near-bottom suspended solids values (mg/1) for transects downstream of dredge at the Head of Lake Pepin, Phase I, 11-2-78



*Data represents arithmetic mean of water samples collected from three sites on each transect.

FIGURE 39 Turbidity values (NTU) for water samples collected from east and west radials at selected distances from the dredge at the Head of Lake Pepin, Phase II, 11-2-78

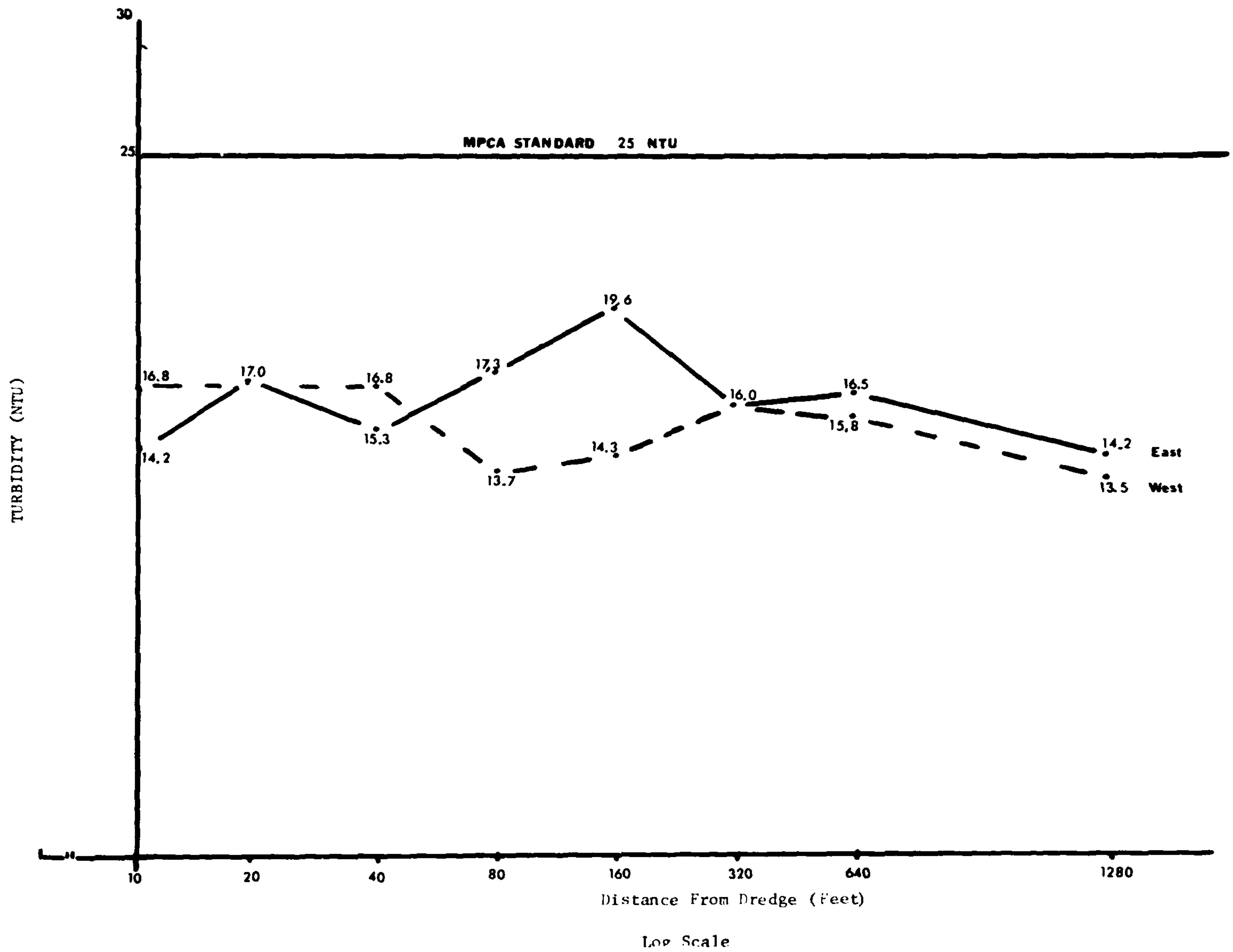


FIGURE 40 Suspended solids values (mg/1) for water samples collected from east and west radials at selected distances from the dredge at the Head of Lake Pepin, Phase II, 11-2-78

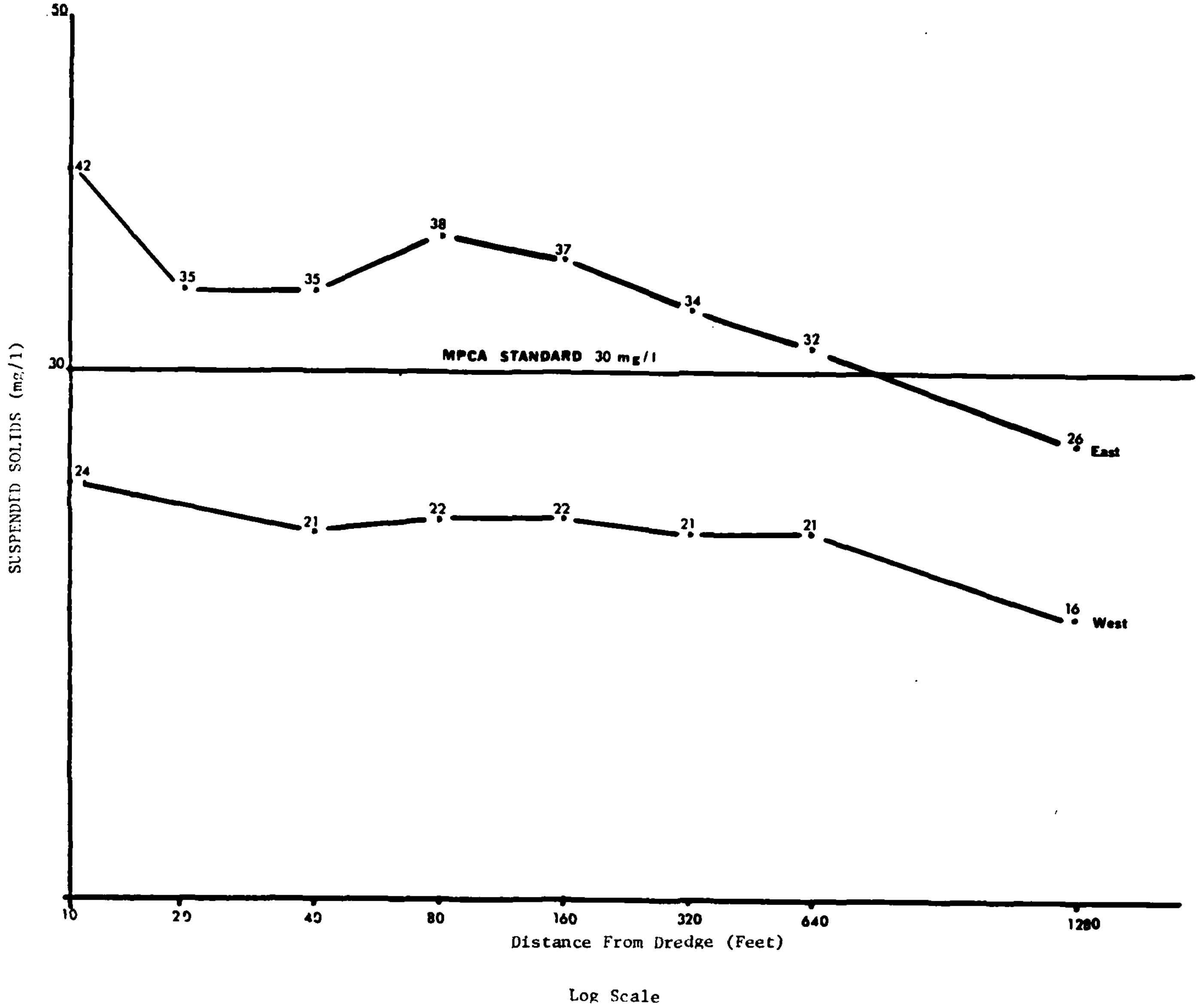


FIGURE 41 Turbidity values (NTU) from samples collected over time from control transect at the Head of Lake Pepin on the Mississippi River, Phase III, 11-2-78

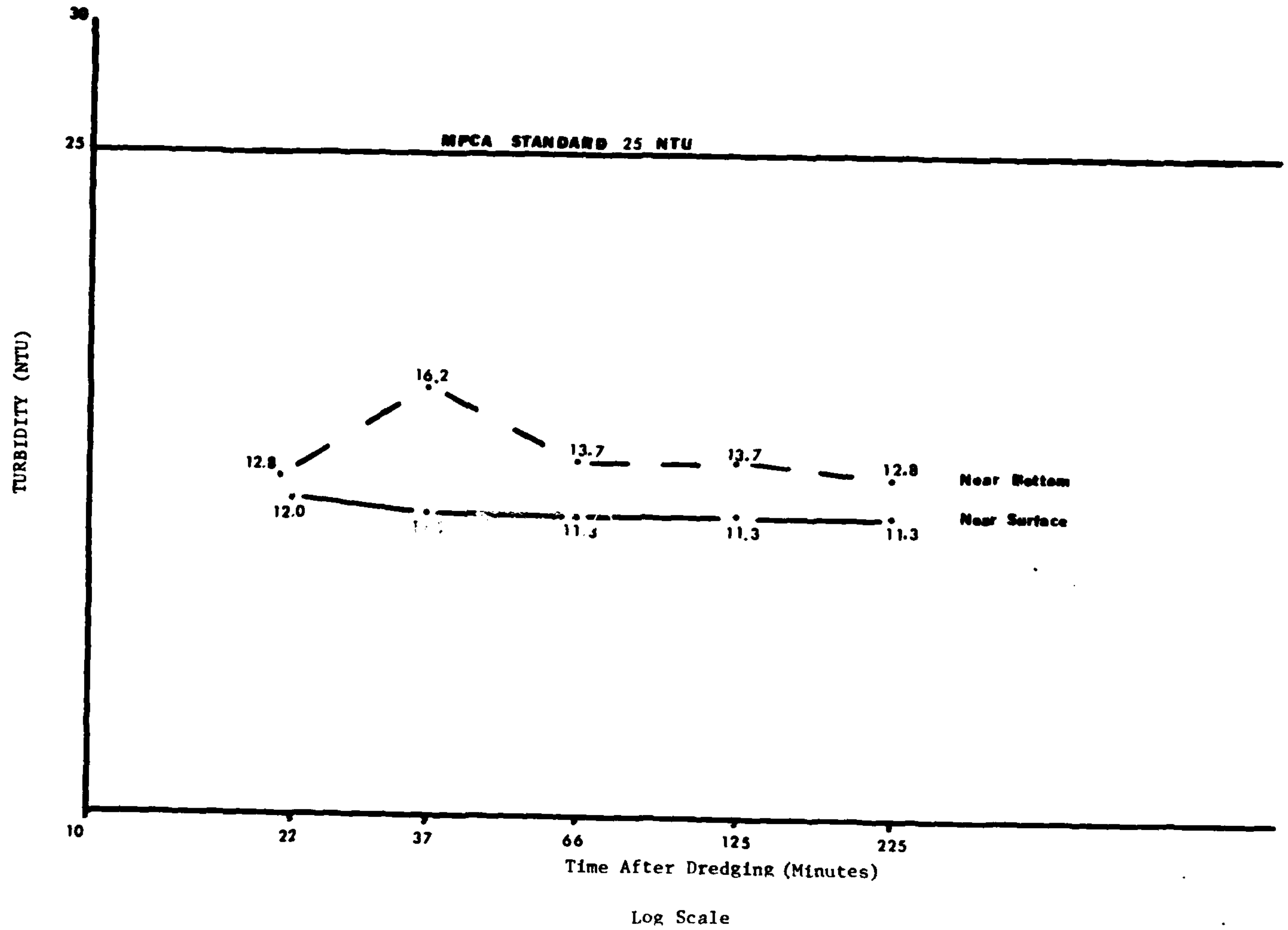


FIGURE 42 Turbidity values (NTU) from samples collected over time from the transect 20 feet downstream of the dredge at the Head of Lake Pepin on the Mississippi River, Phase III, 11-2-78

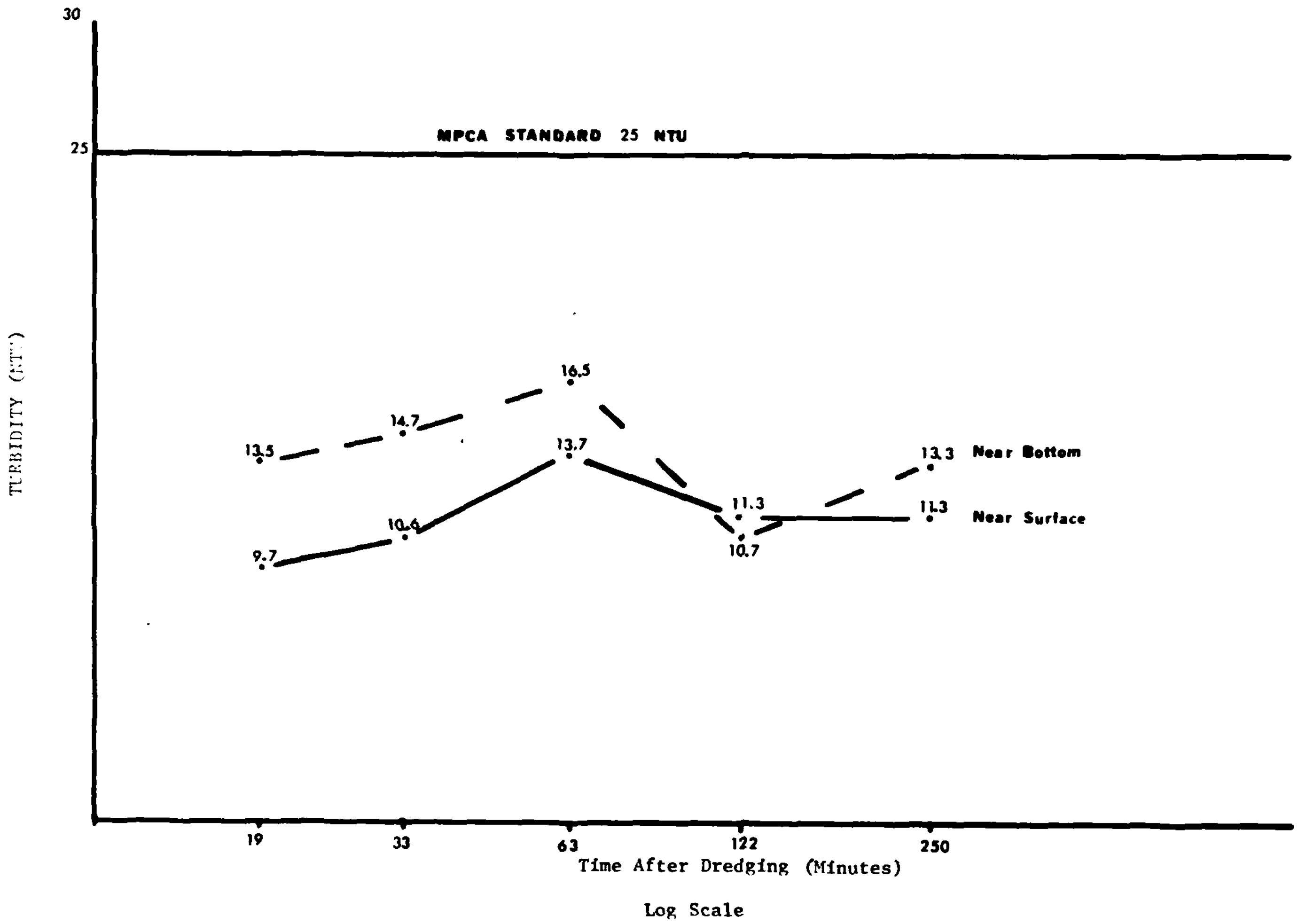


FIGURE 43 Turbidity values (NTU) from samples collected over time from the transect 320 feet downstream of dredge at the Head of Lake Pepin on the Mississippi River, Phase III, 11-2-78

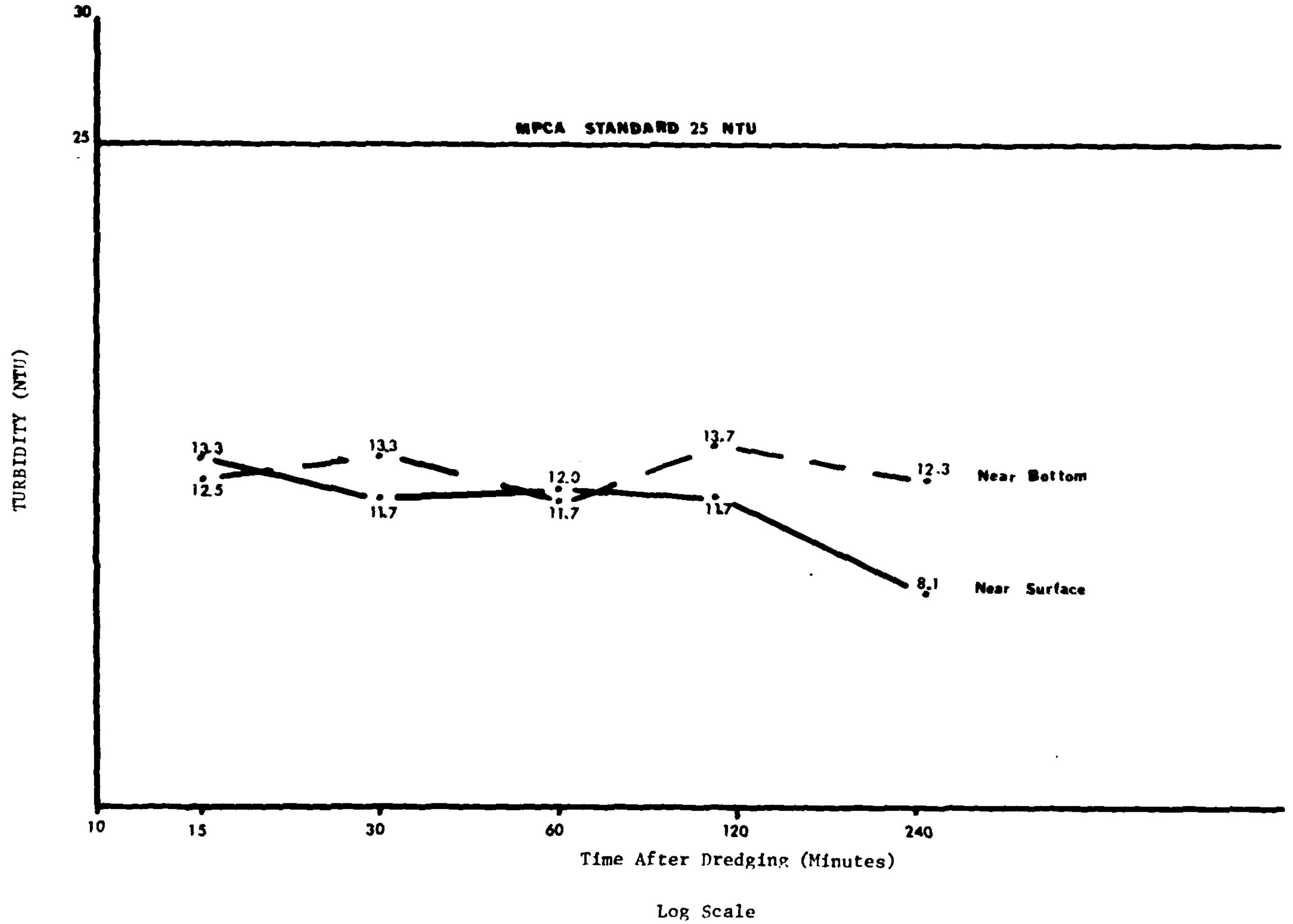


FIGURE 44 Suspended solids values (mg/l) from samples collected over time from the control transect at the Head of Lake Pepin on the Mississippi River, Phase III, 11-2-78

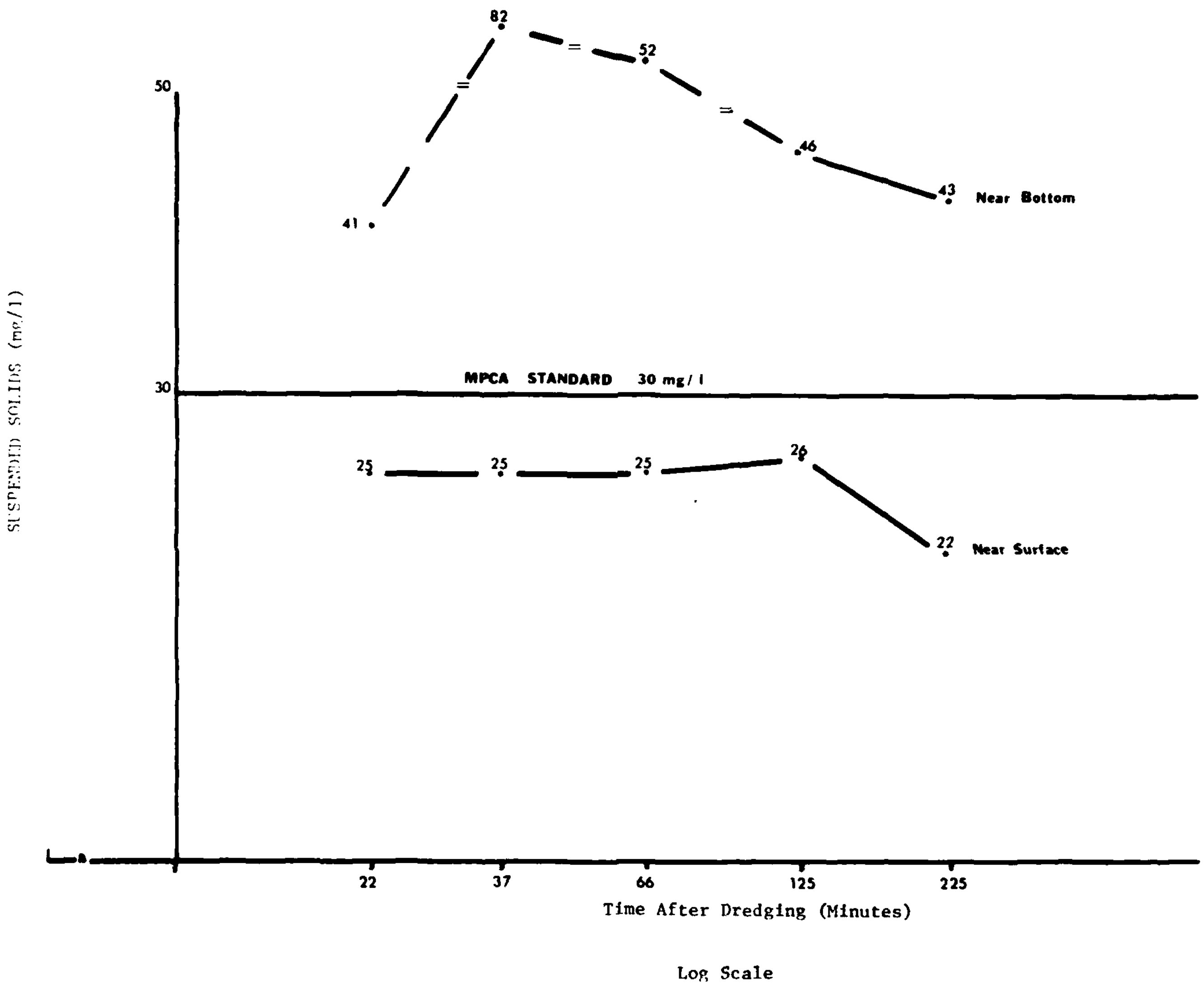


FIGURE 45 Suspended solids values (mg/1) from samples collected over time from the transect 20 feet downstream of dredge at the Head of Lake Pepin on the Mississippi River, Phase III, 11-2-78

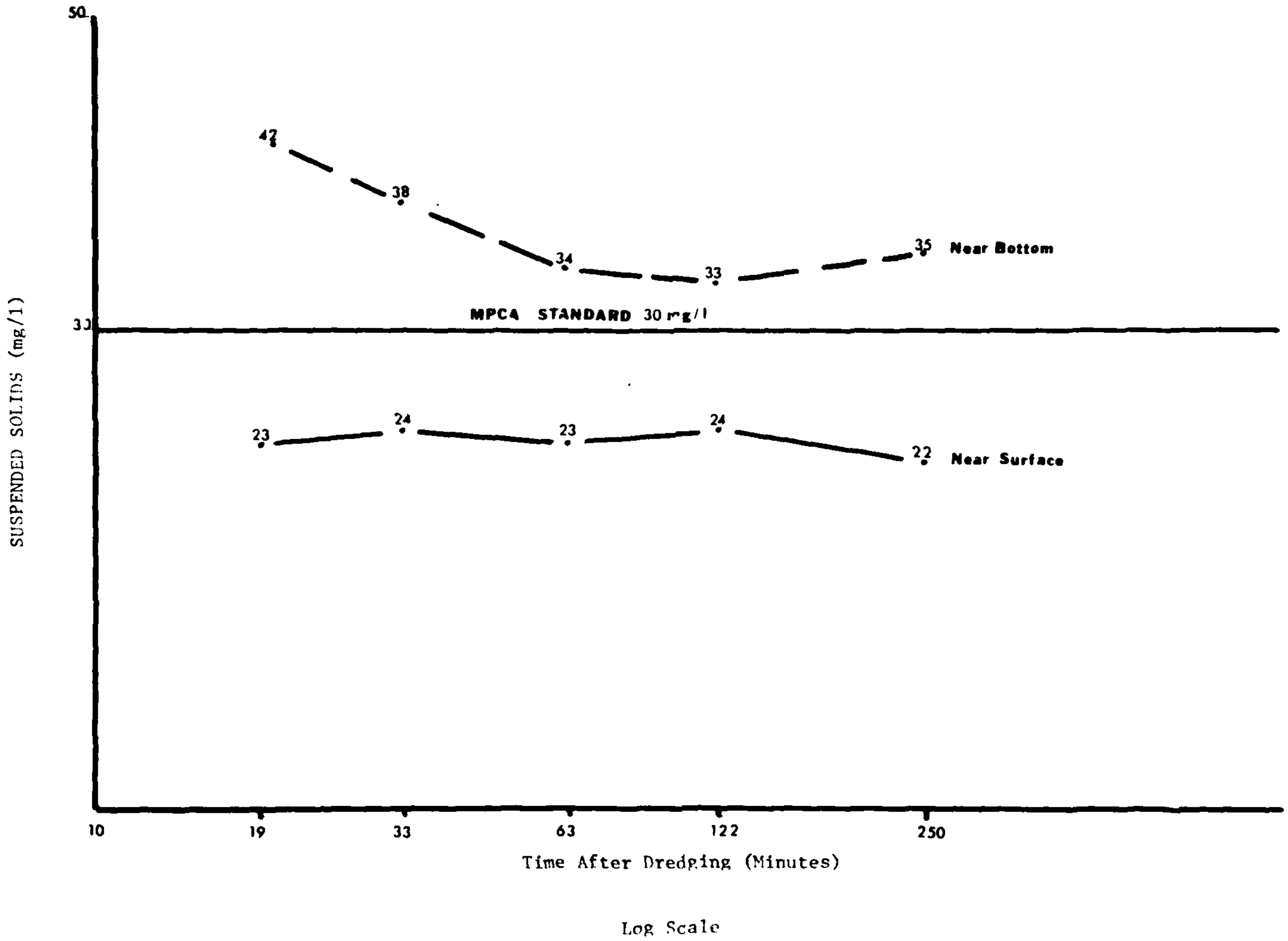
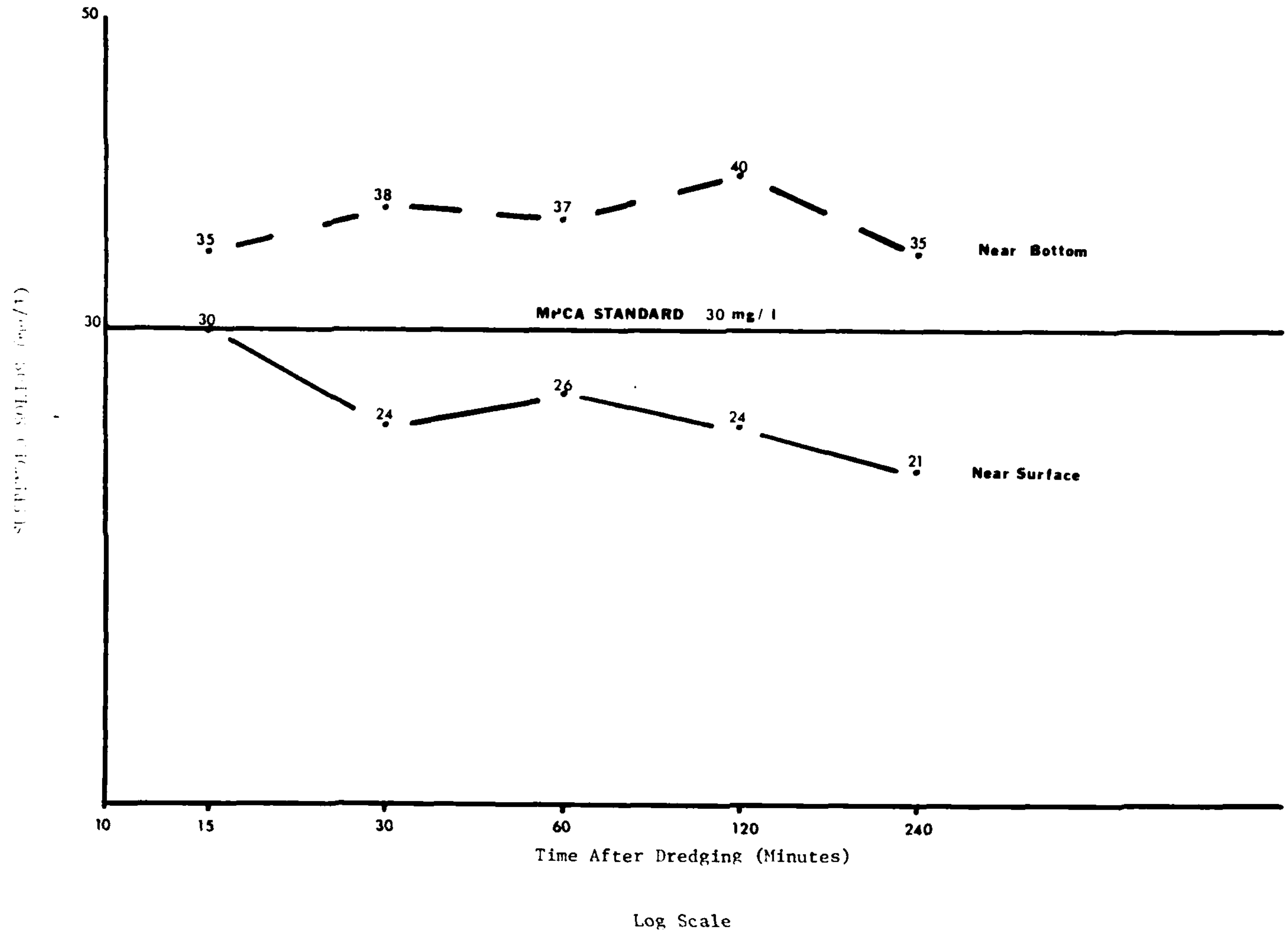


FIGURE 46 Suspended solids values (mg/1) from samples collected over time from the transect 320 feet downstream of dredge at the Head of Lake Pepin on the Mississippi River, Phase III, 11-2-78



1 foot below the surface were within the MPCA standards for this parameter (30 mg/l). The mean concentration of near-surface samples taken below the dredge site (24.1 mg/l) compared favorably with the control site mean of 24.6 mg/l (Table 26B). Samples taken from 1 foot above the bottom all exceeded MPCA standards. However, the control site, located several hundred feet upstream of the dredge site, showed both the highest maximum, 82 mg/l, and the highest mean concentration, 52.8 mg/l, of all 3 sites. The sites 20 feet and 320 feet below the dredge had mean concentrations of 36.4 and 37.0 mg/l, respectively. Concentrations from below the dredge site were consistently lower than concentrations from the control.

The lack of noticeable trends in the data, coupled with the high values found at the control site, makes it difficult to determine the time duration of effects due to dredging. It is likely that the high current velocities which were noted on the day of sampling dissipated the major effects of dredging rather quickly after the operation stopped (within 15 minutes). Fluctuations in parameters noted below the site are probably the combined result of natural fluctuations and minor residual effects.

Comparing the data from phase I (during dredging) with the data from phase III (after dredging) shows an average during-dredging concentration of about 1 NTU and 6 mg/l suspended solids higher than after the dredging concentration (see Table 27).

Table 27 also shows that turbidity and suspended solids concentrations were higher near the bottom than the surface.

TABLE 27 Comparison of Phase III and Phase I Data on Turbidity and Suspended Solids, Head of Lake Pepin

		Turbidity (NTU)		Suspended Solids (mg/l)	
		Surface	Bottom	Surface	Bottom
After dredging	Phase III	11.4	13.5	23	35
During dredging	Phase I	12.6	13.7	28.3	41.6

SUMMARY OF FINDINGS

1. Particle size analysis indicated that the sediments from the upper to middle portion of the historical dredge cut were coarse, consisting mainly of medium to coarse sand-size particles.

2. Bulk chemical analysis of the sediments indicated that the sediments were fairly free of contaminants. The only parameters that showed slightly higher values than what has been reported below Lake Pepin were lead, total Kjeldahl nitrogen, and residue after loss on ignition. PCB's were also detected in the 1 to 2 parts per billion range.

3. No water samples were found to be above the established MPCA turbidity standard of 25 NTU for any portion of this study.

4. Suspended solids were found above the MPCA standard of 30 m 1 mainly in the near-bottom samples. Suspended solids near the bottom were in excess of MPCA's standard in the control sample, downstream of the dredge samples, and after dredging samples. No relationships were found between samples in excess of MPCA standards and distance downstream of dredging or time after dredging.

5. Near-surface and near-bottom turbidity showed no statistically significant difference with distance downstream of the dredge or location within the channel for the phase I sampling. Mean turbidity values for transects downstream of the dredging operation fluctuated within 1 NTU. Turbidity values near the bottom were higher than near the surface, having overall means of 12.6 NTU near the surface and 13.7 NTU near the bottom.

6. For the phase I sampling, suspended solids near the surface and near the bottom did not show any significant trends with distance downstream of the dredge. However, there was a significant difference based on lateral sampling site position in the channel. The center position showed the highest values. Suspended solids mean concentrations for transects downstream of the dredge fluctuated 2 mg/l near the surface and 7 mg/l near the bottom. Near-bottom concentrations of suspended solids were higher than near-surface concentrations, having overall means of 28.3 mg/l near the surface and 41.6 mg/l near the bottom.

7. In phase II, where samples were collected at mid-depth along two radials downstream of the dredge, turbidity showed a lowering of values with distance downstream of the dredge, but by only 1 or 2 NTU. However, this trend was not shown to be statistically significant.

8. Suspended solids in phase II showed a drop within 20 feet of the dredge, a leveling off of values, and a decrease again at 640 feet downstream of the dredge.

9. In the time duration study (phase III), no obvious trends with decay of turbidity or suspended solids during and after dredging stopped were noted. It would appear that any effects caused by the dredge dissipated by the time the first samples were collected (15 minutes).

10. Comparing the mean values after dredging with mean values during dredging, a 1 NTU elevation in turbidity is evident during dredging for both near-surface and near-bottom samples. Suspended solids concentrations were 5-6 mg/l greater during dredging than after dredging for both near-surface and near-bottom samples.

CONCLUSIONS

Analysis of sediments from the dredge cut area revealed that they were composed of mostly coarse, relatively uncontaminated material. This suggests that little potential exists for major water quality impacts as a result of dredging.

Analysis of turbidity data indicates no significant differences in turbidity with distance from the dredge and/or time after dredging. Mean turbidity values were about 1 NTU higher during dredging than after dredging. All sites sampled for turbidity had values well below the MPCA standard of 25 NTU.

Suspended solids data showed very little in the way of trends with either distance or time. A decay trend is evident in phase II in which samples were taken at mid-depth along 2 radials. In this phase, suspended solids values originally in excess of MPCA standards fell below this value within 1280 feet. Suspended solids concentrations in the study were generally highest in near-bottom samples. All near-bottom samples were in excess of MPCA standards for this parameter. However, the control site was also consistently in excess of this standard, indicating that ambient water quality was poor prior to dredging. This complicates the task of distinguishing specific effects due to dredging. In most cases, however, water quality had returned to ambient within a short distance of the dredge and/or soon after dredging had stopped. Near-surface concentrations of suspended solids were all within MPCA standards. No substantial trends were evident in any phase. Mean values from samples collected downstream of the dredge compared favorably to control means, indicating only slight impacts due to dredging.

BOTTOM SEDIMENT RECONNAISSANCE

INTRODUCTION

During the 1978 maintenance dredging season, a bottom sediment reconnaissance was conducted for the navigation portion of the Upper Mississippi River. The bottom sediment reconnaissance consisted of analyzing bottom sediments at selected dredge sites for physical and chemical parameters. The program was designed for management purposes to consider the navigation system as a whole rather than to emphasize specific sites.

The overall objective of the reconnaissance was to assist in the development of appropriate dredged material management plans. In order to accomplish the overall objective, many specific objectives had to be defined. The objectives were: to determine differences in bottom sediment quality between various sampling areas on the Upper Mississippi River; to determine the variability of bottom sediment quality within and among defined sampling areas; to determine the influence of sediment deposition rates (defined by dredging frequencies) on sediment quality; to determine the influence of particle size on sediment quality; to determine the influence of the proximity of major point source discharge(s) on sediment quality; and to determine the retention period necessary to meet effluent standards.

METHODS

EXPERIMENTAL DESIGN

In the design of the bottom sediment reconnaissance, the assumption was made that the river bottom sediments can be segmented into sampling areas based on similarities in their composition. This assumption was based on bottom sediment data collected for a variety of purposes and including different reaches of the Mississippi River from 1974-1977. From these data and past dredging experience, the Upper Mississippi River bottom sediments were segmented into the following sampling areas (see Figure 47):

Area 1. Upper Reach - Head of Navigation to High Bridge (Smith Avenue Bridge). This stretch of the river is very narrow and channelized and flows through the highly urbanized area of the Twin Cities. The sediments in Area 1 range from sandy gravel to gravelly sand (GREAT I WQWG, unpublished). Within this 17-mile stretch of the river, historically, there have been nine dredging sites and an average of 4.4 dredging jobs conducted per year.

Area 2. Pollution Sinks. These were defined from previous sediment data as contaminated, and include the lower portion of Pool 2 and the head of Lake Pepin. The lower portion of Pool 2 is located along and immediately downstream of the Twin Cities area. As a result, the area receives effluent from some of the major discharges into the Upper Mississippi River. Lake Pepin, a large river lake, acts as a settling basin for pollutants. The sediments from this area have been shown to be contaminated. Sediments in these pollution sinks usually are finer than in other areas on the Mississippi River.

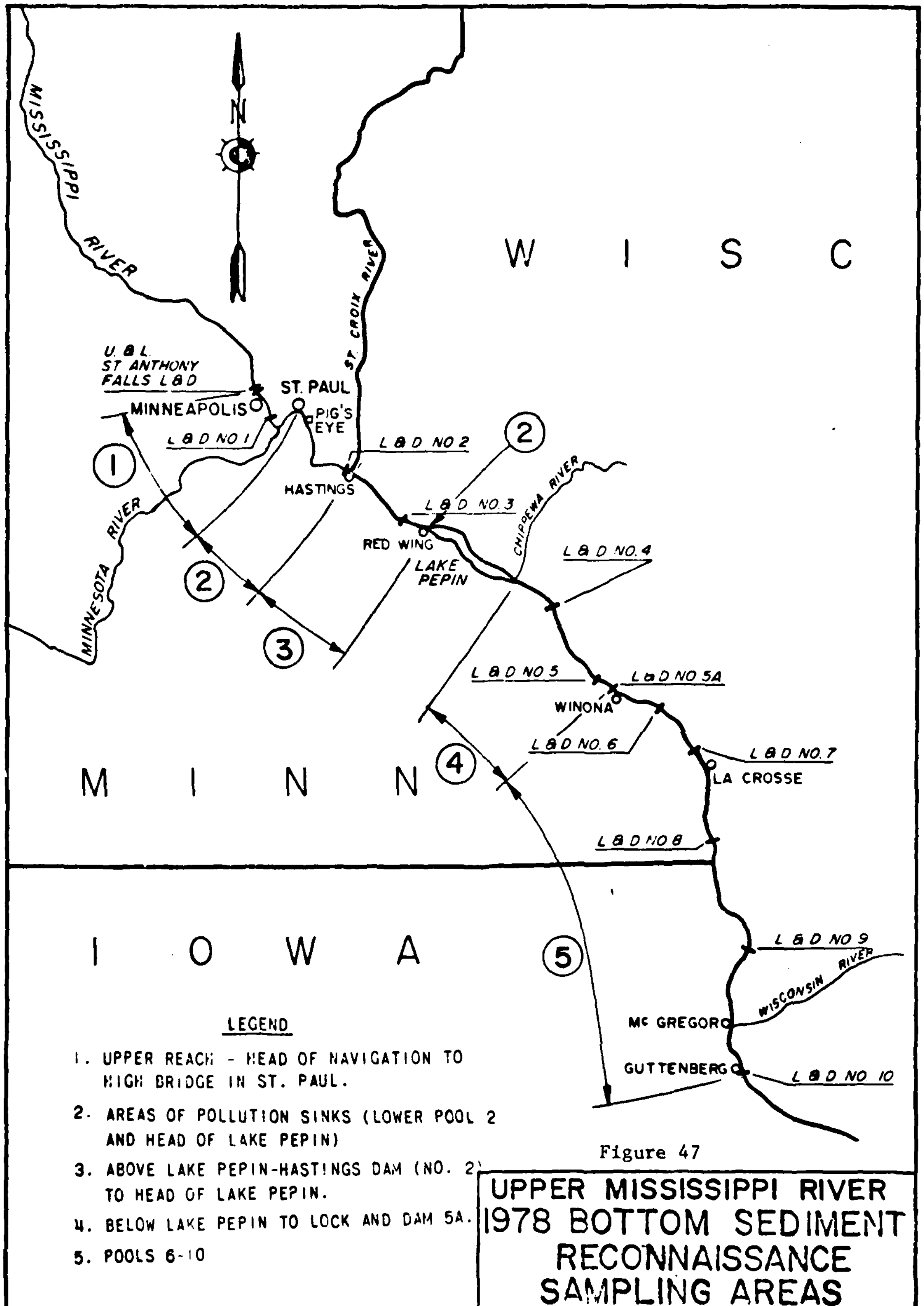


Figure 47

UPPER MISSISSIPPI RIVER
1978 BOTTOM SEDIMENT
RECONNAISSANCE
SAMPLING AREAS

Area 3. Above Lake Pepin - Lock and Dam No. 2 at Hastings, Minnesota to the head of Lake Pepin. The Mississippi River widens through this section of the river. Area 3, located slightly downstream of the Twin Cities area, still receives a major influence from the point and non-point sources in the Twin Cities area. Sediments in Area 3 consist of mainly medium-to-fine sands. Historically, there have been eight dredge sites and 1.70 dredging jobs conducted per year in this 30-mile reach of the river.

Area 4. Below Lake Pepin to Lock and Dam 5A. Water quality and subsequent sediment quality in Area 4 are greatly influenced by the presence of Lake Pepin immediately above the area. Lake Pepin, a large river lake area, acts as a settling basin for pollutants and suspended sediments. In addition, many of the sediment characteristics in Area 4 are the result of the large input of coarse sediments into the Mississippi River from the Chippewa River. Area 4 is 32 miles in length and historically there have been 17 dredging sites and 7.1 dredging jobs conducted per year in this stretch of the river.

Area 5. Pools No. 6-10. The influence of the Chippewa River on sediment characteristics is less in this area than in Area 4, and the sediments usually consist of finer sands than in Area 4. In Area 5, the Mississippi River meanders across a large floodplain. Some of the largest population centers below the Twin Cities Metropolitan Area are located within this reach of the river. Historically, there have been 23 dredge sites and an average of 7.4 dredging jobs conducted per year in this 110-mile reach of the river.

Within each of the five general areas described above, specific dredging sites were organized into three categories based on dredging recurrence intervals. The three categories were defined, based on historical records, as:

Frequent = approximately yearly (50% chance or greater of being dredged in any given year).

Occasional = every 2-3 years (26 to 49% chance of being dredged in any given year).

Infrequent = every 4 years or longer (25% chance or less of being dredged in any given year).

For each of the frequency categories within each of the five general sampling areas, two dredging sites were randomly selected from the set of all dredging sites which satisfied the requirements of the category and sampling area. If there were no dredging sites which satisfied the requirements of the category from one of the general sampling areas, then no samples were collected for that category from that sampling area. If only two or less dredging sites satisfied the conditions of a category from one of the sampling areas, then that site(s) was selected for sampling (see Table 28). From this hierarchal selection process, 26 total sites were sampled in 1978.

Within each selected dredge site a hydraulic evaluation was made to determine where the finer and coarser sediments should be located (e.g., the inside of a bend should have finer sediments than the outside of a bend, etc.). Based on this determination, samples were collected from both the coarser and the finer sediments from within a selected dredging site. If it was

Table 23 1978 Bottom Sediment Reconnaissance for the Mississippi River
Experimental Design and Sampling Code for Bottom Sediment Reconnaissance

Sampling Area		Dredging Frequency					
		Frequent		Occasional		Infrequent	
		Choice 1	Choice 2	Choice 1	Choice 2	Choice 1	Choice 2
I Upper Reach (Head of Navigation to High Bridge in St. Paul)	coarse	IA1	IB1	IC1	ID1	IE1	X
	fine	IA2	IB2	IC2	ID2	IE2	X
II Areas of Pollution Sinks (Lower Pool 2 and Lake Pepin)	coarse	IIA1	X	IIC1	IID1	IIE1	IIF1
	fine	IIA2	X	IIC2 IICC2	IID2	IIE2	IIF2
III Above Lake Pepin (Hastings Dam to Head of Lake Pepin)	coarse	X	X	IIIC1	IIID1	IIIE1	IIIF1
	fine	X	X	IIIC2	IIID2	IIIE2	IIIF2
IV Below Lake Pepin to L/D 5A	coarse	IVA1	IVB1	IVC1	IVD1	IVE1	IVF1
	fine	IVA2	IVB2	IVC2	IVD2	IVE2	IVF2
V Pools 6-10	coarse	VA1	VB1	VC1	VD1	VE1	VF1
	fine	VA2	VB2	VC2	VD2	VE2	VF2

Key to sampling codes

1) X - No dredge site fitting requirements
2) I-V - Sampling areas
3) A-B - frequent
   C-D - occasional
   E-F - infrequent
4) 1 - coarse sediment
   2 - fine sediment

not possible to make a hydraulic determination of particle size, an on-site evaluation was made by probing with a small Ponar dredge. If the on-site evaluation indicated a uniformity of particle sizes at the dredge site, one sample was collected from each half of the site. Subsequently, a total of 52 samples were analyzed from 26 sampling sites (Table 29).

All samples were collected with a modified 9" x 9" Ponar dredge (an unplated dredge, painted with a special non-contaminating paint and fitted with a fine stainless steel screen). Each sample was a composite of three grabs from an approximately 10-foot diameter area of river bottom.

All sediment samples were analyzed for total particle size, settleabliity and bulk chemical constituents. Sediment samples were chilled and shipped to the laboratory as soon after collection as possible.

ANALYTICAL PROCEDURES

Particle Size. Particle size analysis was conducted on all bottom sediment samples by mechanical and hydrometer methods. The analyses were conducted by the U.S. Army Corps of Engineers, Missouri River Division (MRD) Soils Laboratory in Omaha, Nebraska, according to procedures described in EM 1110-2-1906, Laboratory Soils Testing.

Settleability Tests. Settleability tests were conducted on all sediment samples by the U.S. Army Corps of Engineers, Missouri River Division Soils Laboratory in Omaha, Nebraska; 1000 ml slurries were prepared in a graduated cylinder by agitating a 20% solids and river water mixture for 10 minutes. The 4:1 ratio of water to soil was determined by the following computation:

$$VT = 100 \text{ ml} = \frac{Ww + Ws}{Gw \quad Gs}$$

Where VT = Total volume
Ww = Weight of water
Gw = Sp. Gravity, water
Ws = Weight of soil
Gs = Sp. Gravity, soil

For the above calculation, specific gravity tests were run as necessary to establish appropriate values for each sediment type.

Water samples were then withdrawn from the slurry with a suction bulb at the following intervals: 0, 2, 4, 6, 24, 48, 96, and 192 hours or until a concentration of 30 mg/l suspended solids were attained. One 25 ml sample per time interval was withdrawn (5 cm below the surface) for both turbidity and suspended solids analyses.

Bulk Chemical Analysis. Bulk chemical analysis of sediments was conducted by the U.S. Geological Survey Laboratory in Atlanta, Georgia. The analyses were conducted according to EPA approved methods.

Statistical Evaluation. The data were statistically evaluated by Dr. Frank Martin of the University of Minnesota.

TABLE 29 1978 Bottom Sediment Reconnaisance on the Mississippi River

Sampling, Code, and Location of Dredge Cut Sites on the Mississippi River and Other Pertinent Information

Sampling	Area No.	Pool No.	River Mile	Name of Dredge Cut Site	Length in Miles	Frequency of Dredging	Sample I.D. Coarse	Sample I.D. Fine
Upper Reach	I	USAF	856.2	Above & Below Lowry Ave. Br.	1.0	36	IC1	IC2
		1-2	850.2	Above Lake St. Br.	0.6	59	IA1	IA2
			848.7	Below St. Paul Daymark 849.1	0.4	23	IE1	IE2
			848.0	Upper Approach L & D	0.7	36	ID1	ID2
			840.7	Above & Below Smith Ave. Br.	1.3	77	IB1	IB2
Pollution Sinks	II	2&4	839.0	Harriet Island	1.3	41	IIC1	IIC2
			837.2	St. Paul Barge Terminal	1.2	55	IIA1	IIA2
			827.9	Grey Cloud Slough	0.8	23	IIE1	IIE2
			823.2	Pine Bend Foot Light	1.0	27	IID1	IID2
			784.6	Wacouta Point	1.6	9	IIF1	IIF2
Above Pepin	III	3&4	811.0	Prescott	1.4	27	IIIC1	IIIC2
			807.8	Four-mile Island - Truedale	1.6	23	IIIE1	IIIE2
			801.9	Coulters Is. - Morgan Coulee	2.2	36	IIID1	IIID2
			792.8	Cannon River	1.4	18	IIIF1	IIIF2
Below Pepin	IV	4,5,5A	759.0	Above Crats Island	1.0	73	IVA1	IVA2
			757.5	Above Teepeeota Point	0.9	68	IVB1	IVB2
			754.2	Beef Slough	0.7	32	IVC1	IVC2
			741.5	Mt. Vernon Light	0.4	14	IVE1	IVE2
			733.6	Fountain City	0.5	23	IVF1	IVF2
			731.5	Head of Betsy Slough	1.0	36	IVD1	IVC2
Pools 6-10	V	6-10	720.8	Homer		18	VE1	VE2
			708.5	Winters Landing	0.7	36	VC1	VC2
			690.3	Above Brownsville	1.5	53	VA1	VA2
			677.9	Island 126	0.9	18	VF1	VF2
			665.4	Indian Camp Light	0.8	32	VD1	VD2
			664.3	Lansing Upper Light	1.1	50	VB1	VB2

RESULTS

GENERAL

Chlorinated Hydrocarbons and Other Biocides. Aldrin, endosulfan, heptachlor-epoxide, heptachlor, lindane, mirex, polychlorinated naphthalenes (PCN), perthane, and toxaphene were not found at or above the detection limits at any of the sites studied on the Upper Mississippi River (see Appendix Table F-1). With the exception of endosulfan, mirex and PCN which were not tested for in 1974, these parameters were also found to be below the levels of detection in the 1974 bottom sediment study (GREAT I WQWG, 1978a). Therefore, the threat to the aquatic environment, in terms of toxicity or bioaccumulation of these parameters when sediments are resuspended by dredging, is minimal.

Chlordane, DDD, DDE, DDT, dieldrin, endrin, and polychlorinated biphenyls (PCB's) were all detected in sediments from at least one dredge site studied in 1978. With the exception of two sites in Pools 4 and 5A which had PCB's at detectable levels, detectable levels of these parameters were limited to sites above Lock and Dam No. 2 at Hastings, Minnesota. This upper portion of the navigational system flows through the Twin Cities, and subsequently a multitude of point discharges and extensive urban runoff occurs in this area. In addition, the land in the immediate watershed of this portion of the river is extensively farmed and non-point pollution is an important problem.

Metals. Arsenic, chromium, copper, and nickel were found at detectable levels mainly in zones I and II, above Lock and Dam No. 2 at Hastings, Minnesota (see Appendix Table F-1). Detectable levels of arsenic occurred at only 4 of the 26 sites sampled in 1978 and ranged from 1-3 micrograms per gram (ug/g). Chromium values ranged from <10 to 30 ug/g in the study area. Chromium values of 10 ug/g or greater occurred at 6 of the 26 sites sampled, of which only two were not in either zones I or II. Copper values ranged from <10 to 100 ug/g in the study area and values of 10 ug/g or greater occurred at only four sites, all of which were in either zones I or II. Nickel values in the study area ranged from <10 to 40 ug/g and values equal to or greater than 10 ug/g occurred in 7 of the 26 sites sampled in 1978. Please note that sites recorded as 100 ug/g were not included in this comparison. All but two of these sites were in zones I and II.

Barium, manganese, iron, and zinc were found above the detection limits in all of the zones studied. Barium values ranged from <10 to 210 ug/g. Values for barium over 30 ug/g were found mainly in zones I, II, and IV and in the high and moderate frequency sites. Iron and manganese were prevalent throughout the study area. Iron values ranged from 1,200 to 14,000 ug/g and manganese ranged from 12 to 1,900 ug/g. Zinc values in the study area ranged from <10 to 400 ug/g. Only 4 of the 26 sites studied had values for zinc greater than 20 ug/g and these were all above Lock and Dam No. 2 at Hastings, Minnesota. All four of these parameters are naturally occurring and abundant on the Upper Mississippi River. Fortunately, all except zinc are relatively non-toxic to man and to aquatic organisms and in the case of manganese, iron, and zinc, are essential trace nutrients (EPA, 1976).

Lead showed some interesting trends that were different from the other metals studied. Lead concentrations equal to or greater than 10 ug/g were encountered quite frequently above Lock and Dam No. 2, but none of the sample sites from Lock and Dam No. 2 to Lock and Dam No. 5a (zones III and IV) had detectable lead levels. Please note that samples recorded as $<$100 were not included in this comparison. Lead then reappears below Lock and Dam No. 5a and detectable levels of lead are encountered quite frequently in zone V. A possible explanation of this trend is that one of the most important mechanisms of lead entering the environment is from the internal combustion engine; the lead is subsequently carried by rain and meltwater via storm sewers to the aquatic environment. This, coupled with the fact that the areas with detectable levels of lead are also areas of urban concentrations, seems to explain the trend that was observed.

Mercury was occasionally found throughout the study area. Concentrations of mercury ranged from 0.00 to 2.2 and were detected at 10 of the 26 sites sampled in the study area. Detectable levels of mercury were mainly limited to the low frequency dredging sites. Comparing the results of this study to a 1974 bottom sediment study (GREAT I, WQWG, 1978a) indicates that generally much lower values for mercury were recorded during this study than in 1974.

Chemical oxygen demand (COD) and residue lost on ignition (LOI) (Appendix Table F-1). COD varied considerably within the study area and ranged from 1,200 to 73,000 mg/kg. Zones III-V showed fairly consistent readings, with one exception (IV-E-1), and only ranged from 1,200 to 2,800 mg/kg. Zones I and II showed a wider range of values, varying from 1,900 to 73,000 mg/kg; however, they were consistently higher than the values recorded in zones III-V. In fact, 5 of the 10 sites sampled in zones I and II had COD values over 10,000 mg/kg.

Residue (LOI) values ranged from 681 to 123,000 mg/kg; however, all but three of the sites (in zones 1 and 2) sampled had values considerably less than 10,000 mg/kg. Zone IV showed the lowest overall concentration of residue (LOI). This is probably attributable to the influence of the Chippewa River in this stretch of the Mississippi River.

Nutrients (Appendix Table F-1). Kjeldahl nitrogen values in the study area ranged from 22 to 9,800 mg/kg. All but 8 of the 26 sites sampled in 1978 had Kjeldahl nitrogen values of less than 500 mg/kg. Of the eight sites which had Kjeldahl nitrogen over 500 mg/kg, all but two were located in Zones 1 and 2 of the Upper Mississippi River.

Ammonia nitrogen concentrations varied from 0.5 to 490 ug/g within the study area. Ammonia nitrogen values over 10 ug/g occurred only at the three sites having greater than 40% fine material (clays and silts).

Total phosphorous concentrations ranged from 14 to 1,100 ug/g within the study area. All five of the zones had occasional high phosphorous concentrations, suggesting the influence of point source discharges.

Particle Size. Particle size analyses revealed that most of the sediments studied consisted mainly of sand (see Appendix F, Table F-4). Typically, within the study area, fine and medium grained sand particles constituted more than 95% of the total particle size distribution. For the most part, fine materials (silts and clays) and coarse material (coarse sand and gravel) were found only in trace amounts. Of the sites showing trace amounts of fine material (1-10%) the fine material was mainly made up of silts rather than clays.

However, in four of the 26 sites sampled in 1978, fine materials constituted more than 10% of the total particle size distribution. Three of these sites were in Pools 1 and 2 and one was in Pool 4 (Head of Lake Pepin - RM 784.6)(IIF1, F2). These same four sites also accounted, in the bulk chemical analyses, for most of the detectable levels of arsenic, chromium, copper, cyanide, and nickel. In addition, most of the relatively high values that were recorded for PCB's, barium, COD, iron, lead, manganese, Kjeldahl nitrogen, ammonia nitrogen, total phosphorous, residue (LOI), and zinc occurred at these sites. This corroborates the work done by others in which, barring the influence of the close proximity of a point or non-point source of contaminants, it has been demonstrated that contaminants tend to associate with the finer sediments (GREAT I WQWG, 1978).

In zones III through V, the finer sediments within these zones were found at sites near the mouths of tributaries or in places where the main channel meanders through a large open-water area. For example, site III F was located near the mouth of the Cannon River and had a greater percentage of particles passing through an 80-mesh screen than did any other site within this zone. However, even at the sites having finer sediments, the sediments in these three zones were relatively coarse, and silts and clays were found only in trace amounts.

Settleability. Settleability tests were designed to approximate the effects of hydraulic dredging and of subsequent settling of the material in a confined disposal area. In the evaluation of the 1978 settleability results (Appendix F, Tables F-2 and F-3), one must look at the initial concentration after agitation of the sediments and ambient riverwater mixture to determine the maximum turbidity and suspended solids generation potential for a particular sediment. The second procedure in evaluating the results is to look at the settling time or concentration of suspended material at a given time after agitation to determine the length of time needed to reach a certain concentration for a particular sediment.

Turbidity and suspended solids showed similar trends. Initial turbidity and suspended solids values ranged from 14-45,000 FTU and 64-189,804 mg/l, respectively. The four sites that had more than 10% fine material (silts and clays) were the only ones which showed initial turbidity values over 10,000 FTU and suspended solids concentrations over 20,000 mg/l.

Initial turbidity and suspended solids values over 300 FTU and 1,000 mg/l were mainly limited to sediment samples having 3% or greater composition of silts and clays and 7% finer than fine sands (<80 mesh screen). With two exceptions, RM 664.3 and 741.8, initial turbidity values over 300 and suspended solids over 1,000 mg/l were limited to zones I and II and occurred at 10 of the 26 sites sampled in 1979. After 4 hours settling, turbidity values for these samples ranged from 30 to 340 FTU and suspended solids ranged from 68 to 404 mg/l.

Of the 54 sediment samples, 42 had initial turbidity values less than 300 FTU and suspended solids concentrations of 1,000 mg/l. At the end of 4 hours settling time all the values for these 42 samples were well below 100 FTU, and at the end of 24 hours of settling, all were below 40 FTU with most of them being below 30 FTU. At the end of 24 hours of settling time all suspended solids concentrations were less than 100 mg/l and most were below 60 mg/l.

STATISTICAL EVALUATION

The data in Tables 30, 31, and 32 are subject to drastically skewed variations caused by sampling and the presence of point sources of contaminants. Such skewness and the large numbers of data recorded as being below detection sensitivity or below the lowest number the lab publishes make sample means an unsatisfactory summary of the data. The study does not afford precise estimation of average concentrations. Such a goal would have required massive expenditures which would not be justified by the utility of such information. The study illustrates ranges, presence and absence, and the relative comparison among the levels of each factor. The study was intended to be analytical in nature, with the detection of differences among zones as a major goal. The nature of this data suggests the use of rank statistics for these analytical purposes. The Friedman analysis of variance for ranked data is used in analysis.

Analysis by Zone. In each zone, data is collected at six factorial designations (frequency by sediment size) and the five zones are comparable at each of these levels. At each of these six levels the approximately ten observations were used to rank the zones from 1 (for least contaminated) to 5 (for most contaminated). This was done for each of the 15 parameters mentioned in Tables 31 and 32. On each parameter a 6-by-5 Friedman two-way analysis of variance was conducted to test for significant differences between zones. An example of this analysis is presented for manganese in Table 30. All other analyses in Tables 31 and 32 are similar. In Table 30 the ranks in quotes were estimated or supplied by missing value techniques and the statistical test is done on the rank sums at the bottom of the table which also supply overall or average rankings of zones.

Table 30 Rank Analysis of Manganese by Zone

Sample Level	Zone I Rank	Zone II Rank	Zone III Rank	Zone IV Rank	Zone V Rank
Frequent Coarse	2	1	3	4	5
Frequent Fine	4	5	2	3	1
Occasional Coarse	2	3	4	5	1
Occasional Fine	2	5	2	4	2
Infrequent Coarse	3	2	5	4	1
Infrequent Fine	2	3	5	4	1
R = rank sum	15	19	21	24	11
(r) = average rank	(2)	(3)	(4)	(5)	(1)

The ranks were determined directly from the data in Appendix F. The missing values are supplied by a procedure which protects the validity of the Rank Sum Test. In this example the rank sum statistic is not statistically significant at $p<.05$. A summary of the analyses of 12 parameters is presented in Table 31. Statistically significant differences between zones are noted by * for $p<.05$ and ** for $p<.01$.

Table 31 Rank Analysis by Zone: Chemical Parameters

Parameter	Zone I R(r)	Zone II R(r)	Zone III R(r)	Zone IV R(r)	Zone V R(r)
Barium	16(3)	15.5(2)	13(1)	25.5(5)	20(4)
COD**	27(4.5)	27(4.5)	11.5(1.5)	11.5(1.5)	13(3)
Iron*	17(3)	25.5(5)	23(4)	15(2)	9.5(1)
Lead**	25.5(5)	23(4)	10(1.5)	10(1.5)	21.5(3)
Manganese	15(2)	19(3)	21(4)	24(5)	11(1)
Mercury	13(1)	20(4)	19(3)	23(5)	15(2)
Kjeldahl Nitrogen	24(4.5)	24(4.5)	11(1.5)	19.5(3)	11.5(1.5)
NH_4 Nitrogen	22(4)	25(5)	18(3)	12.5(1.5)	12.5(1.5)
Nickel	25(5)	23(4)	14(2)	14(2)	14(2)
Phosphorus	20(3)	23(5)	14(2)	21(4)	12(1)
Residue (LOI)**	22.5(4)	24(5)	16(2)	6(1)	21.5(3)
Zinc*	25(5)	24(4)	17(3)	14(2)	10(1)
Total for (r)**	44	50	28.5	33.5	24
Rank Overall	(4)	(5)	(2)	(3)	(1)

The test for significant differences between zones was conducted on the overall rank sum at the bottom of Table 31 and was highly significant. Zone II with overall rank (5) had the consistently highest parameter values with Zone I next highest. Zone V was lowest but not far below zone III. Of specific interest in Table 31 is the high rank of lead in zone V, which includes Winona and La Crosse. COD is much elevated in zones I and II, and Residue (LOI) was very consistently lowest in zone IV. Zinc shows a graduation inversely related to distance downriver.

Table 32 presents the same analysis of ranks for the physical parameters in Appendix Tables F-2, F-3, and F-4.

Table 32 Rank Analysis by Zone: Physical Parameters

	Zone I	Zone II	Zone III	Zone IV	Zone V
Characteristic	R(r)	R(r)	R(r)	R(r)	R(r)
% of Fine Sediment	21.5(4)	26.5(5)	13.5(2)	14(2)	14.5(2)
Suspended Solids at 4 hr.	12.5(2)	24.5(5)	12(1)	13(3)	13.5(4)
Turbidity at 4 hr.	17.5(4)	23.5(5)	11.5(2)	12(3)	10.5(1)
Total for (r)	10	15	5	8	7
Rank Overall	(3.5)	(5)	(1)	(3.5)	(2)

In the cases of suspended solids and turbidity, lowest rank means clearest water in the test results. Zone III was clearest and zone II was murkiest. Zone II was in fact defined to be those parts of the dredge cut population where high amounts of fines could be found.

Samples IA2 (68% fines), IIA2 (83% fines), IIC2 (68% fines), and IIF2 (22% fines) were drastically higher in fines than all others and IIF2 is a distant fourth in this set. Especially the first three of these samples contained the high (or in some cases detectable) levels of PCB's, chlordane, DDE, arsenic, chromium, and copper in Appendix Table F-1. They also accounted for the very high levels of all other parameters in Table F-1. There is clearly a very strong relationship between fines and elevated levels of contaminants.

The effect of point sources on the data is illustrated in particular in the IVD samples which show unusually and consistently high levels of phosphorous and barium. They are known to be in close downstream proximity to the Fountain City treatment plant effluent source.

General conclusions are that zone II dredge sites are most contaminated, with zone I a close second. Zones I and II also contain sites with very high levels of fines. Zone III has dredge sites with the cleanest physical parameters and zone V has sites with the lowest chemical parameters. Zones III, IV, and V are relatively comparable and substantially below zones I and II. All these conclusions are stated in the context of being on the average.

Analysis by Frequency. The same rank analysis is done but the layout now consists of 3 columns for dredging frequency and 10 sample levels for zone by particle size. Tables 33 and 34 contain the chemical and physical analyses respectively. The only parameter which showed a statistically significant difference due to frequency of dredging was COD. COD was highest in frequently dredged sediments and consistently low in infrequently dredged sediments. Infrequently dredged sediments were generally lower but with two notable exceptions in the chemical parameters, Nitrogen and Mercury, where they were highest.

Table 33 Rank Analysis by Frequency: Chemical Parameters

	Frequent	Occasional	Infrequent
Parameter	R(r)	R(r)	R(r)
Barium	22.5(3)	20(2)	17.5(1)
COD*	25(3)	21(2)	14(1)
Iron	22.5(3)	21.5(2)	16(1)
Lead	14.5(3)	10.5(1)	11(2)
Manganese	20.5(2)	25(3)	14.5(1)
Mercury	17(1)	19.5(2)	23.5(3)
Kjeldahl Nitrogen	14(1)	22.5(2)	23.5(3)
NH_4 Nitrogen	16(1)	22(2.5)	22(2.5)
Nickel	11(2)	12(3)	7(1)
Phosphorus	19(2)	23.5(3)	17.5(1)
Residue (LOI)	19(1.5)	22(3)	19(1.5)
Zinc	19(2)	25.5(3)	15.5(1)
Total for (r)	24.5	28.5	19
Rank Overall	(2)	(3)	(1)

The physical parameters in Table 34 show no significant differences due to dredging frequency, but do suggest a minor and tentative contradiction insofar as frequently dredged sites showed high levels of fine material but were also the ones which settled more quickly. There is no effective ranking by physical characteristics.

Table 34 Rank Analysis by Frequency: Physical Parameters

Characteristic	Frequent R(r)	Occasional R(r)	Infrequent R(r)
% Fine Sediment	21.5(3)	20(2)	18.5(1)
Suspended Solids at 4 hr.	18.5(1)	19(2)	22.5(3)
Turbidity at 4 hr.	16(1)	24(3)	20(2)
Total for (r)	5	7	6
Overall rank	(1)	(3)	(2)

SUMMARY OF FINDINGS

1. Biocides and PCB contamination of the sediments were mainly found in zones I and II, in relatively low concentrations.

2. Heavy metals followed metal-specific trends. Arsenic, chromium, copper, and nickel were detected in only a few sites within the study area and these sites were mainly limited to zones I and II, whereas barium, manganese, iron, and zinc were distributed throughout the system. Lead distribution seemed to be closely associated with proximity to urban areas. Mercury was found occasionally throughout the study area.

3. Kjeldahl nitrogen and ammonia nitrogen showed a wide range of values within the study area, but extremely high concentrations were limited to the samples having more than 40% fine material (clays and silts). Occasional high values of total phosphorous occurred throughout the study area suggesting the influence of point dischargers.

4. Particle size analysis indicated that most of the sediments studied were coarse and would be classified as sand. Fine material was found only in trace amounts, except at four sites which had more than 10% fine material. These same four sites accounted for most of the detectable levels or high concentrations of the chemical parameters that were investigated in this study. In zones III through V, the finer sediments within these zones were found at sites near the mouths of tributaries or where the main channel meanders through a large open-water area.

5. Initial turbidity and suspended solids in the settleability tests corresponded well with the amount of fine material present. Initial turbidity and suspended solids values over 300 FTU and 1,000 mg/l respectively were mainly

limited to sediment samples having 3% or greater composition of silts and clays and 7% finer than fine sands (<80 mesh screen). These occurred mainly in zones I and II. After 4 hours settling, turbidity and suspended solids values for these samples ranged from 30 to 340 FTU and 68 to 404 mg/l, respectively.

Of the sediment samples tested, 78% (42 of 54) had initial turbidity values less than 300 FTU and suspended solids values less than 1,000 mg/l. At the end of 24 hours of settling time, all values were below 40 FTU and 100 mg/l.

6. All the data were statistically analyzed by Friedman analysis of variance for ranked data to determine the statistical differences among the five zones and the three categories of dredging frequency. Chemical oxygen demand (COD) was the only parameter that showed a statistical difference ($\alpha = .05$) among the three categories of frequency of dredging. COD was highest at the frequently dredged sites and lowest at the infrequently dredged sites.

7. Of the chemical parameters statistically analyzed, COD, iron, lead, residue lost on ignition, and zinc showed statistical differences among the five zones. Zinc showed a steady decrease going downriver, with the highest levels in zone I and the lowest in zone V. COD was highest in zones I and II. Iron was highest in zones II and III and generally showed a decrease going downriver from the Twin Cities metropolitan area. Lead and residue lost on ignition followed somewhat similar trends, being generally comparably the highest in zones I, II, and V.

An overall ranking based on all the chemical parameters of the zones indicates that zone II was the worst, followed closely by zone I. The overall cleanest was zone V.

8. Rank analysis of the percent of fine material and the suspended solids and turbidity readings at the end of 4 hours indicates that overall, zone II was the worst. Zone III was the cleanest.

CONCLUSIONS

Zone designations showed substantial and statistically significant differences in levels of chemical and physical parameters. Frequency of dredging at a site was a less important factor.

Very high levels (and in some cases detectable levels) of chemical parameters were closely associated with exceptionally high levels of fine materials in the sediments.

The nature of the data and the scope of this study did not allow precise estimates of average levels present, but the data were adequate for ranking by zones on levels of contamination. Zones I and II were most heavily loaded with contaminants, while zones III, IV and V were substantially lower. Zone V, the farthest from the major source of pollutants, the Twin Cities metropolitan area, was the least contaminated overall.

REFERENCES

Anderl, W.H. 1978. Minnesota Pollution Control Agency. Personal communication.

Claflin, T.O. 1976. "Resuspension of Sediments due to hydraulic dredging, silt screen, polymers." Mimeographed Report to St. Paul District, U.S. Army Corps of Engineers, St. Paul, Minnesota. 12 pp.

Great River Environmental Action Team I - Water Quality Work Group. 1978a. "A Pilot Study on Effects of Hydraulic Dredging and Disposal on Water Quality of the Upper Mississippi River (July 1976)." Published by the U.S. Army Corps of Engineers, St. Paul, Minnesota.

Great River Environmental Action Team I - Water Quality Work Group. 1978b. "Effects of Clamshell (Mechanical) Dredging and Disposal on Water Quality of the Upper Mississippi River." Published by U.S. Army Corps of Engineers, St. Paul, Minnesota.

Great River Environmental Action Team I - Water Quality Work Group. 1979. "Final Report to GREAT I TEAM." 79 pp.

Grimes, D.J. 1975. Release of sediment-bound fecal coliforms by dredging. Applied Microbiology 29(1):109=111.

Held, J.W. 1978. "Environmental Impact of Dredged Material Disposal on the Upper Mississippi River at Crosby Slough." U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. DMRP Miscellaneous Paper D-78-2. 84 pp.

Lee, G. Fred. 1977. "Corps of Engineers Criteria Project on Upper Mississippi River (Grey Cloud Slough Dredging Operation)." Mimeographed report to the U.S. Army Corps of Engineers Waterways Experiment Station. Institute for Environmental Sciences, University of Texas at Dallas. 54 pp.

Marking, L.L., and T.D. Bills. 1977. "Acute Effects of Silt and Sand Sedimentation on Freshwater Mussels." A study conducted for the St. Paul District, Corps of Engineers by the U.S. Fish and Wildlife Service, Fish Control Laboratory in La Crosse, Wisconsin. 13+ pp.

McHenry, J.R. and Ritchie, J.C. 1976. Sedimentation of Fines in Pools and Backwater Lakes of Lock and Dam No. 4 through No. 10 on the Upper Mississippi River. Sedimentation Laboratory, Oxford, Mississippi. Contract report submitted to Great River Environmental Action Team (GREAT) I - Sediment Erosion Work Group.

Minnesota Pollution Control Agency. 1975a. "Investigation of the U.S.C.E. Dredging Operation on the Mississippi River at Richmond Island - August 1, 1975." Division of Water Quality, Section of Surface and Groundwaters. MPCA, Roseville, Minnesota. 11 pp.

Minnesota Pollution Control Agency. 1975b. "Investigation of the U.S.C.E. Dredging Operations on the Mississippi River at Grey Cloud Island - September 10, 1975." Division of Water Quality, Section of Surface and Groundwaters, MPCA, Roseville, Minnesota. 10 pp.

Minnesota Pollution Control Agency. 1978. "Minnesota Lakes and Streams." A Compilation of Analytical Data for 1970-1975. Volume 8. Two Parts. 1074 pp.

Minnesota Pollution Control Agency. 1978. "Minnesota Lakes and Streams." Compilation of Analytical Data for October 1975 - September 1977. Volume 1. 483 pp.

..., R. H. Tatem, A. Gibson, and S. Pedron. 1980. "Biological Assessment of Upper Mississippi River Sediments." U.S. Army Engineers Waterways Experiment Station, Vicksburg, Mississippi. Miscellaneous Paper ...-80-

U.S. Army Corps of Engineers, Army Engineer District, St. Paul, Minnesota. 1973. "Final Environmental Impact Assessment of the Northern Section of the Upper Mississippi River - Pool 2." Prepared by North Star Research Institute, Minneapolis, Minnesota. 211 pp. and 131 pp. Appendixes.

U.S. Army Corps of Engineers, Army Engineer District, St. Paul. 1974. "Final Environmental Impact Statement: Operation and Maintenance, 9-foot Navigation Channel, Upper Mississippi River, Head of Navigation to Guttenberg, Iowa." St. Paul, Minnesota. Two volumes.

APPENDIXES:

TECHNICAL APPENDIXES

RAW DATA APPENDIXES

DREDGED MATERIAL DISPOSAL APPENDIX

CONTRACTOR'S APPENDIX

APPENDIX
TABLE OF CONTENTS

TECHNICAL
APPENDIXES

APPENDIX A
WATER QUALITY MONITORING OF DREDGING OPERATIONS AT READ'S LANDING, 8/14/78 - 8/15/78, SUMMARY OF RESULTS FROM STATISTICAL EVALUATION OF DATA

TABLE A-1 Analysis of Variance (ANOVA) for Near-Surface Turbidity Values, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	1.2	.30	1.58
Site Location	3	2.5	.83	4.36*
Error	12	2.31	.19	
Total	19			

TABLE A-2 Analysis of Variance (ANOVA) for Near-Bottom Turbidity Values, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	0.6	0.15	0.83
Site Location	3	1.2	0.4	2.22
Error	12	2.2	0.183	
Total	19			

TABLE A-3 Analysis of Variance (ANOVA) for Near-Surface Suspended Solids Value, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	213.7	53.4	2.4
Site Location	3	166.5	55.5	2.5
Error	12	265.6	22.1	
Total	19			

TABLE A-4 Analysis of Variance (ANOVA) for Near-Bottom Suspended Solids Values, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	166.3	41.5	1.0
Site Location	3	126.2	42.0	1.0
Error	12	497.2	41.4	
Total	19			

* Significant at α = .05
df = degrees of freedom
ss = sum of squares
ms = mean square

TABLE A-5 Analysis of Variance (ANOVA) for Near-Surface Turbidity Values, Phase II

Variable	df	ss	ms	f-value
Transect Distance	5	770.98	0.196	2.5
Site Location	2	0.48	0.24	3.07*
Error	10	0.78	0.078	
Total	17			

TABLE A-6 Analysis of Variance (ANOVA) for Near-Bottom Turbidity Values, Phase II

Variable	df	ss	ms	f-value
Transect Distance	5	0.92	0.184	2.875
Site Location	2	0.04	0.02	0.30
Error	10	0.64	0.064	
Total	17			

TABLE A-7 Analysis of Variance (ANOVA) for Near-Surface Suspended Solids Values, Phase II

Variable	df	ss	ms	f-value
Transect Distance	5	59.25	11.8	0.60
Site Location	2	42.06	21.0	1.06
Error	10	199.2	19.9	
Total	17			

TABLE A-8 Analysis of Variance (ANOVA) for Near-Bottom Suspended Solids Values, Phase II

Variable	df	ss	ms	f-value
Transect Distance	5	217.8	43.6	2.13
Site Location	2	11.3	5.2	0.25
Error	10	205.63	20.5	
Total	17			

APPENDIX B
WATER QUALITY MONITORING OF DREDGING OPERATIONS
AT UPPER LANSING LIGHT,
SUMMARY OF RESULTS FROM STATISTICAL EVALUATION OF DATA

TABLE B-1 Analysis of Variance (ANOVA) Comparing Near-Surface Turbidity Data Among Transects Up- and Downstream of the Effluent Pipe and Sampling Site Locations on the Transects, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	14.5	3.665	1.02
Site Location	2	14.3	7.15	2.01
Interaction	8	6.42	0.80	--
Error	15	53.28	3.55	
Total	29			

TABLE B-2 Analysis of Variance (ANOVA) Comparing Near-Bottom Turbidity Data Among Transects Up- and Downstream of the Effluent Pipe and Sampling Site Locations on the Transects, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	413.89	103.4	21.6**
Site Location	2	22.4	11.2	23.0*
Interaction	8	11.2	1.4	2.9
Error	15	7.17	0.48	
Total	29			

TABLE B-3 Analysis of Variance (ANOVA) Comparing Near-Surface Suspended Solids Data Among Transect Up- and Downstream of the Effluent Pipe and Sampling Site Locations on the Transects, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	269.5	67.4	2.5
Site Location	2	332.5	166.2	6.2*
Interaction	8	161.9	20.2	0.8
Error	15	403.5	26.9	
Total	29			

* - Significant at α = .05
** - Significant at α = .01

TABLE B-4 Analysis of Variance (ANOVA) Comparing Near-Bottom Suspended Solids Data Among Transects Up- and Downstream of the Effluent Pipe and Sampling Site Locations on the Transects, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	75.5	18.9	0.4
Site Location	2	355.4	177.5	3.8*
Interaction	8	310.9	38.9	0.8
Error	15	706.5	47.1	
Total	29			

TABLE B-5 Analysis of Variance (ANOVA) Comparing Near-Surface Turbidity Data Among Transects Up- and Downstream of the Cutterhead and Sampling Site Locations on the Transects, Phase II

Variable	df	ss	ms	f-value
Transect Distance	3	12.8	4.3	7.0*
Site Location	2	19.6	9.8	16.0**
Interaction	6	4.3	0.72	1.2
Error	12	7.3	0.61	
Total	23			

TABLE B-6 Analysis of Variance (ANOVA) Comparing Near-Bottom Turbidity Data Among Transects Up- and Downstream of the Cutterhead and Sampling Site Locations on the Transects, Phase II

Variable	df	ss	ms	f-value
Transect Distance	3	16.6	5.53	1.58
Site Location	2	6.7	3.35	.9
Interaction	6	35.1	5.84	1.67
Error	12	41.9	3.49	
Total	23			

TABLE B-7 Analysis of Variance (ANOVA) Comparing Near-Surface Suspended Solids Data Among Transects Up- and Downstream of the Cutterhead and Sampling Site Locations on the Transects, Phase II

Variable	df	ss	ms	f-value
Transect Distance	3	155.2	51.7	6.9*
Site Location	2	763	381	50.0**
Interaction	6	54.6	9.1	1.2
Error	12	90	7.5	
Total	23			

TABLE B-8 Analysis of Variance (ANOVA) Comparing Near-Bottom Suspended Solids Data Among Transects Up- and Downstream of the Cutterhead and Sampling Site Locations on the Transects, Phase II

Variable	df	ss	ms	f-value
Transect Distance	3	127	42.3	3.2
Site Location	2	355	178	13.8**
Interaction	6	439	73	5.6*
Error	12	155	12.9	
Total	23			

APPENDIX C
WATER QUALITY MONITORING OF DREDGING OPERATIONS
IN POOL 1 OF THE UPPER MISSISSIPPI RIVER,
SUMMARY OF RESULTS OF STATISTICAL ANALYSIS OF
TURBIDITY AND SUSPENDED SOLIDS DATA

TABLE C-1 Analysis of Variance (ANOVA) for Near-Surface Turbidity Values, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	1.70	0.425	1.89
Site Location	2	2.27	1.13	5.0 *
Error	8	1.8	0.225	
Total	14			

TABLE C-2 Analysis of Variance (ANOVA) for Near-Bottom Turbidity Values, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	7.51	1.87	0.67
Site Location	2	23.65	11.82	4.26*
Error	8	22.15	2.77	
Total	14			

TABLE C-3 Analysis of Variance (ANOVA) for Near-Surface Suspended Solids Values, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	11.6	2.9	0.52
Site Location	2	25.4	127	23.1*
Error	8	44.0	5.5	
Total	14			

TABLE C-4 Analysis of Variance (ANOVA) for Near-Bottom Suspended Solids Values, Phase I

Variable	df	ss	ms	f-value
Transect Distance	4	114.0	28.5	1.86
Site Location	2	41.2	20.6	1.34
Error	8	122.2	15.3	
Total	14			

* Significant at = .05

TABLE C-5 Analysis of Variance (ANOVA) for Near-Surface Turbidity Values, Phase II

Variable	df	ss	ms	f-value
Site Distance	[illegible]	1.31	0.262	0.19
Radial	[illegible]	0.01	0.01	0.007
Error	[illegible]	6.59	1.32	
Total	11			

TABLE C-6 Analysis of Variance (ANOVA) for Near-Bottom Turbidity Values, Phase II

Variable	df	ss	ms	f-value
Site Distance	[illegible]	1.595	0.319	0.56
Radial	1	0.375	0.375	0.66
Error	5	2.84	0.568	
Total	11			

TABLE C-7 Analysis of Variance (ANOVA) for Near-Surface Suspended Solids Values, Phase II

Variable	df	ss	ms	f-value
Site Distance	5	50.75	10.1	0.4
Radial	1	90.75	90.75	3.5
Error	5	124.75	24.9	
Total	11			

TABLE C-8 Analysis of Variance (ANOVA) for Near-Bottom Suspended Solids Values, Phase II

Variable	df	ss	ms	f-value
Site Distance	5	380.8	76.2	1.99
Radial	1	24.1	24.1	0.63
Error	5	191.4	38.3	
Total	11			

APPENDIX D

SUMMARY OF STATISTICAL EVALUATION OF THE TURBIDITY AND SUSPENDED SOLIDS DATA FROM PHASE I, WATER QUALITY STUDY AT THE HEAD OF LAKE PEPIN

TABLE D-1 Analysis of Variance (ANOVA) for Near-Surface Turbidity Data, Phase I

Variable	df	ss	ms	f-value
Transect Distance	3	0.26	0.087	0.17
Site Location	2	0.57	0.285	0.56
Error	6	3.03	0.505	
Total	11			

TABLE D-2 Analysis of Variance (ANOVA) for Near-Bottom Turbidity Data, Phase I

Variable	df	ss	ms	f-value
Transect Distance	3	3.15	1.05	0.3
Site Location	2	3.18	1.59	0.5
Error	6	18.9	3.15	
Total	11			

TABLE D-3 Analysis of Variance (ANOVA) for Near-Surface Suspended Solids Data, Phase I

Variable	df	ss	ms	f-value
Transect Distance	3	4.92	2.46	4.39
Site Location	2	162.0	54	96.4**
Error	6	3.33	0.56	
Total	11			

TABLE D-4 Analysis of Variance (ANOVA) for Near-Bottom Suspended Solids Data, Phase I

Variable	df	ss	ms	f-value
Transect Distance	3	77.7	25.9	1.2
Site Location	2	925.3	462	22**
Error	6	126	21	
Total	11			

* Significant at $\alpha = 0.05$
**Significant at $\alpha = 0.01$

RAW DATA
APPENDIXES

APPENDIX E WILD'S BEND DREDGE CUT DATA

TABLE E-1 Bulk chemical analysis of sediments collected from Wild's Bend dredge cut (R.M. 730.8) on 9/19/78 (analyses conducted by U.S. Geological Survey laboratory, Atlanta, Georgia).

PARAMETER \ SITE	1 EAST	1 WEST	2 EAST	2 WEST	3 EAST	3 WEST	4 EAST	4 WEST
Arsenic	0	0	0	0	0	0	0	0
Barium	50	30	60	50	30	30	30	30
Cadmium	<10	<10	<10	<10	<10	<10	<10	<10
Chromium (Tot)	<10	<10	<10	<10	<10	<10	<10	<10
COD	1200	900	1200	2600	1900	1200	1900	620
Copper	<10	<10	<10	<10	<10	<10	<10	<10
Cyanide	0	0	0	0	0	0	0	0
Iron	1700	1500	2100	1700	1700	2000	1800	1800
Lead	<10	10	<10	<10	<10	<10	<10	<10
Manganese	460	320	650	490	360	320	360	330
Mercury	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N KJD	160	170	180	140	250	220	190	170
N, NH_4 as N	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.0
Nickel	<10	<10	<10	<10	<10	20	<10	<10
Oil and grease	0	0	0	0	0	0	0	0
Phos. (Tot)	85	51	55	140	160	70	170	58
Res. LOI.	3860	5020	6170	5410	3560	4050	3560	3270
Zinc	<10	<10	<10	10	<10	<10	<10	<10
Pesticides ug/kg								
Aldrin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chlordane	0	0	0	0	0	0	0	0
DDD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dieldrin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Endosulfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Endrin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hept. Epox.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heptachlor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lindane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mirex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCB	0	0	0	0	0	0	0	0
PCN	0	0	0	0	0	0	0	0
Perthane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Toxaphene	0	0	0	0	0	0	0	0

Note: Unless otherwise stated, values are in mg/kg.

TABLE E-2 Total concentration in water for selected parameters and sampling sites at the Wild's Bend dredge cut

	SAMPLING SITE	ARSENIC UG/L	CADMIUM UG/L	TOT ORG CARBON MG/L	CHLORIDE DISS MG/L	CHROMIUM TOT UG/L	COD HI LEVEL MG/L	COPPER UG/L	CYANIDE MG/L	IRON UG/L	LEAD UG/L	MANGANESE UG/L	MERCURY UG/L	NICKEL UG/L	NH_4 NITROGEN MG/L	TOT NITROGEN MG/L	NO_3 NITROGEN MG/L	TOT ORG NITROGEN MG/L	KJELDAHL NITROGEN MG/L	NO_2 and NO_3 MG/L	OIL and GREASE MG/L	PHENOLS MG/L	TOT ORTHO PHOS. MG/L	SULFIDE MG/L	ZINC US/L	RESIDUE DIS 180°C MG/L	RESIDUE TOT 105°C MG/L	RESIDUE SUSP 105°C MG/L	RESIDUE SUSP* 105°C MG/L	TURBIDITY NTU	TURBIDITY *
Background 9-19-78	USW - Top	2	16	11	8.4	<10	38	3	0.00	1000	130	130	<0.5	6	0.01	1.1	4.9	0.58	0.59	0.52	0.0	--	0.12	0.0	20	168	208	27	24	14	12.0
	USE - Top	2	19	14	7.7	<10	41	3	0.00	1100	220	140	<0.5	20	0.02	1.4	6.0	0.84	0.86	0.49	0.0	--	0.11	0.2	70	165	201	31	34	15	7.3
	NBBC - Top	2	8	17	8.1	<10	42	5	0.00	1100	70	140	<0.5	31	0.02	1.4	6.0	0.82	0.84	0.51	0.0	--	0.11	0.3	50	163	204	32	35	15	9.8
	DSW - Top	2	11	9.0	8.5	20	42	4	0.00	810	150	110	<0.5	10	0.01	1.2	5.1	0.62	0.63	0.52	0.0	--	0.12	0.0	20	170	193	15	31	7.0	8.0
	DSE - Top	2	22	14	7.8	<10	42	3	0.00	830	260	130	<0.5	20	0.02	1.3	5.8	0.80	0.82	0.50	0.0	--	0.11	0.2	40	163	200	27	--	10.0	--
	USW - Bottom	2	12	11	8.3	10	36	4	0.00	1000	130	120	<0.5	6	0.02	1.2	5.4	0.60	0.62	0.59	0.0	--	0.12	0.0	20	156	193	16	32	8.0	10.5
	USE - Bottom	1	10	15	7.8	10	43	3	0.00	1100	98	140	<0.5	9	0.03	1.4	6.3	0.88	0.91	0.51	0.0	--	0.11	0.3	30	156	196	29	24	10	6.8
	NBBC - Bottom	2	13	14	7.8	<10	39	3	0.00	760	96	110	<0.5	23	0.02	1.3	5.8	0.78	0.80	0.51	0.0	--	0.11	0.2	50	159	201	24	33	10	8.1
	DSW - Bottom	2	10	11	--	<10	37	5	0.00	810	140	120	<0.5	12	0.01	1.2	5.4	0.70	0.71	0.51	0.0	--	0.12	0.0	40	--	195	--	34	9.0	8.0
	DSE - Bottom	2	18	15	7.8	<10	39	3	0.00	1100	190	130	<0.5	11	0.02	1.3	5.8	0.78	0.80	0.51	0.0	--	0.11	0.3	40	166	195	22	--	10	--
During Dredging 9-21-78	Cont-W-Top	2	10	11	8.7	<10	45	4	0.00	810	140	110	<0.5	6	0.01	1.3	5.7	0.71	0.72	0.56	0.0	0	0.12	0.0	20	174	202	31	24	8.0	13.0
	Cont-C-Top	2	11	11	8.1	10	38	5	0.00	1000	95	130	<0.5	9	0.01	1.1	5.0	0.58	0.59	0.55	0.0	2	0.13	0.0	30	170	199	22	22	8.0	8.3
	Cont-E-Top	1	8	11	8.5	<10	44	4	0.00	1000	95	160	<0.5	17	0.02	1.5	6.7	0.98	1.00	0.51	1	0	0.13	0.0	20	172	197	29	24	9.0	7.8
	25-W-Top	2	14	11	8.1	10	42	3	0.00	870	120	140	<0.5	6	0.03	1.4	6.2	0.82	0.85	0.55	0.0	0	0.12	0.0	20	176	194	25	28	8.0	7.2
	25-E-Top	2	12	11	8.0	<10	42	3	0.00	870	150	130	<0.5	7	0.02	1.3	5.9	0.77	0.79	0.54	0.0	0	0.13	0.0	20	166	196	25	18	7.0	7.6
	600-W-Top	2	9	13	8.1	10	38	2	0.00	1000	52	140	<0.5	5	0.01	1.2	5.2	0.63	0.64	0.54	0.0	0	0.12	0.0	20	167	199	21	18	9.0	7.5
	600-C-Top	1	7	10	8.3	<10	51	4	0.00	850	99	140	<0.5	10	0.02	1.4	6.1	0.84	0.86	0.52	0.0	0	0.13	0.0	30	164	196	34	26	8.0	8.2
	600-E-Top	2	10	10	8.2	10	38	4	0.00	1000	110	140	<0.5	8	0.02	1.2	5.2	0.63	0.56	0.53	0.0	0	0.12	0.0	40	154	197	21	27	8.0	8.5

TABLE F-2 (Cont.)

SAMPLING SITE \ PARAMETER	ARSENIC UG/L	CADMIUM UG/L	TOT ORG CARBON MG/L	CHLORIDE DISS MG/L	CHROMIUM TOT UG/L	COD HI LEVEL MG/L	COPPER UG/L	CYANIDE MG/L	IRON UG/L	LEAD UG/L	MANGANESE UG/L	MERCURY UG/L	NICKEL UG/L	NH_4 NITROGEN MG/L	TOT NITROGEN MG/L	NO_3 NITROGEN MG/L	TOT ORG NITROGEN MG/L	KJELDAHL NITROGEN MG/L	NO_2 and NO_3 MG/L	OIL and GREASE MG/L	PHENOLS MG/L	TOT ORTHO PHOS. MG/L	SULFIDE MG/L	ZINC UG/L	RESIDUE DIS 180°C MG/L	RESIDUE TOT 105°C MG/L	RESIDUE SUSP 110°C MG/L	RESIDUE SUSP* 105°C MG/L	TURBIDITY NTU	[illegible]
During Dredging 9-21-78																														
Cont-W-Bottom	2	12	11	8.7	10	49	4	0.00	1000	95	130	<0.5	5	0.01	1.2	5.1	0.60	0.61	0.55	0.0	0	0.14	0.0	20	175	208	32	16	9.0	8.9
Cont-C-Bottom	2	7	10	8.2	<10	49	4	0.00	780	63	120	<0.5	8	0.01	1.2	5.1	0.60	0.61	0.55	0.0	2	0.13	0.0	20	169	203	23	30	9.0	8.0
Cont-E-Bottom	1	11	11	8.3	<10	40	4	0.00	600	150	110	<0.5	11	0.02	1.5	6.5	0.93	0.95	0.52	0.0	0	0.13	0.0	80*	167	198	21	31	8.0	8.4
25-W-Bottom	2	12	12	8.0	10	40	5	0.00	1000	99	140	<0.5	11	0.02	1.4	6.2	0.84	0.86	0.55	0.0	0	0.12	0.0	30	166	197	23	13	9.0	7.9
25-E-Bottom	2	12	11	7.9	<10	44	4	0.00	840	110	130	<0.5	11	0.02	1.4	6.1	0.82	0.84	0.54	0.0	1	0.13	0.0	20	166	200	33	11	8.0	8.6
600-W-Bottom	2	18	12	8.0	10	39	4	0.00	1100	260	140	<0.5	7	0.02	1.1	5.0	0.58	0.60	0.53	0.0	0	0.12	0.0	10	166	199	27	34	9.0	13.3
600-C-Bottom	1	10	11	8.3	<10	39	3	0.00	700	52	130	<0.5	11	0.02	1.5	6.6	0.96	0.98	0.51	0.0	0	0.13	0.0	20	168	194	24	18	9.0	6.8
600-E-Bottom	2	15	11	8.2	<10	38	7	0.00	1000	230	130	<0.5	13	0.03	1.3	5.5	0.69	0.72	0.53	0.0	0	0.12	0.0	50	168	178	20	33	9.0	7.9
During Dredging 9-22-78																														
DP-1	2	11	12	8.4	10	50	6	0.00	4600	88	2000	<0.5	13	0.04	1.4	6.0	0.76	0.80	0.55	0.0	2	0.14	0.0	20	164	252	39	--	21	--
DP-2	2	13	15	8.1	10	43	6	0.00	6300	120	2500	<0.5	17	0.07	1.8	7.9	1.1	1.2	0.58	0.0	0	0.17	0.0	40	172	230	53	--	30	--
Con-W-Top	2	11	11	8.3	<10	41	6	0.00	820	92	130	<0.5	16	0.01	1.4	6.2	0.86	0.87	0.58	0.0	0	0.12	0.0	20	165	193	18	42	8.0	8.6
Con-C-Top	1	7	11	8.1	<10	43	2	0.00	750	29	130	<0.5	20	0.02	1.4	6.0	0.81	0.83	0.52	0.0	0	0.13	0.0	30	171	197	25	14	8.0	8.6
BW-Top	2	3	11	8.1	<10	43	4	0.00	830	45	130	<0.5	14	0.02	1.5	6.4	0.88	0.90	0.55	0.0	0	0.13	0.0	30	172	194	30	15	9.0	7.7
BE-Top	2	8	13	8.0	<10	43	3	0.00	820	100	140	<0.5	7	0.02	1.6	6.9	0.98	1.0	0.55	0.0	1	0.13	0.0	20	168	195	24	20	7.0	8.7
100-W-Top	1	9	11	8.4	<10	45	5	0.00	1000	32	130	<0.5	7	0.01	1.4	6.4	0.89	0.90	0.54	--	1	0.13	0.0	20	167	200	26	17	9.0	8.3
100-C-Mid	2	11	12	8.4	<10	43	3	0.00	750	47	140	<0.5	11	0.01	1.4	6.2	0.85	0.85	0.55	--	0	0.12	0.0	20	172	193	21	37	8.0	8.7

TABLE E-2 (Cont.)

During Dredging 9-22-78

SAMPLING SITE \ PARAMETER	ARSENIC UG/L	CADMIUM UG/L	TOT ORG CARBON MG/L	CHLORIDE DISS MG/L	CHROMIUM TOT UG/L	COD HI LEVEL MG/L	COPPER UG/L	CYANIDE MG/L	IRON UG/L	LEAD UG/L	MANGANESE UG/L	MERCURY UG/L	NICKEL UG/L	NH_4 NITROGEN MG/L	TOT NITROGEN MG/L	NO_3 NITROGEN MG/L	TOT ORG NITROGEN MG/L	KJELDAHL NITROGEN MG/L	NO_2 and NO_3 MG/L	OIL and GREASE MG/L	PHENOLS MG/L	TOT ORTHO PHOS MG/L	SULFIDE MG/L	ZINC UG/L	RESIDUE DIS 180°C MG/L	RESIDUE TOT 105°C MG/L	RESIDUE SUSP 110°C MG/L	RESIDUE SUSP* 105°C MG/L	TURBIDITY NTU	TURBIDITY *
100-E-Mid	2	14	13	8.2	10	41	3	0.00	1000	93	240	<0.5	13	0.03	1.3	5.9	0.75	0.78	0.55	0.0	0	0.12	0.0	20	177	190	19	23	8.0	8.8
200-W-Top	2	11	10	8.4	20	45	2	0.00	910	110	130	<0.5	7	0.01	1.7	7.5	0.99	1.0	0.69	—	2	0.13	0.0	10	167	201	25	19	7.0	9.1
200-C-Mid	2	6	13	8.2	<10	40	3	0.00	780	31	140	<0.5	6	0.01	1.4	6.0	0.80	0.81	0.55	0.0	0	0.12	0.0	10	174	192	19	28	8.0	8.1
200-E-Mid	2	17	12	8.1	<10	53	3	0.00	1100	210	210	<0.5	7	0.02	1.5	6.5	0.89	0.91	0.56	0.0	1	0.12	0.0	20	166	189	19	26	8.0	7.7
300-W-Top	2	7	9.9	8.1	<10	36	2	0.00	770	79	120	<0.5	5	0.01	1.1	4.9	0.54	0.55	0.55	--	0	0.12	0.0	20	168	200	18	26	8.0	7.9
300-C-Top	2	12	11	8.2	<10	53	3	0.00	1100	110	140	<0.5	6	0.01	1.2	5.1	0.01	0.62	0.54	0.0	1	0.12	0.0	10	177	203	24	15	10.0	8.3
300-E-Top	2	14	14	8.3	<10	45	3	0.00	1000	94	180	<0.5	8	0.03	1.5	6.5	0.87	0.90	0.56	0.0	0	0.12	0.0	10	175	194	21	22	8.0	8.2
400-W-Top	1	2	12	8.2	<10	41	3	0.00	820	77	140	<0.5	9	0.01	1.5	6.8	0.97	0.98	0.55	--	0	0.12	0.0	40	175	195	19	20	8.0	8.0
400-C-Top	2	3	13	8.4	<10	41	4	0.00	920	30	110	<0.5	12	0.01	1.5	6.6	0.84	0.85	0.63	0.0	1	0.13	0.0	20	164	196	25	21	7.0	7.7
400-E-Top	2	12	12	8.3	<10	46	3	0.00	1000	150	140	<0.5	7	0.02	1.5	6.8	0.95	0.97	0.56	0.0	0	0.12	0.0	10	174	198	24	7	8.0	8.0
950-W-Top	1	5	11	8.4	<10	44	4	0.00	850	47	140	<0.5	7	0.02	1.5	6.6	0.92	0.94	0.55	--	1	0.12	0.0	20	169	199	27	25	8.0	8.9
950-C-Top	1	9	12	8.2	<10	44	3	0.00	820	130	140	<0.5	10	0.01	1.4	6.2	0.84	0.85	0.56	--	1	0.16	0.0	20	172	202	18	22	9.0	8.9
950-E-Top	1	15	11	8.3	10	38	3	0.00	880	15[illegible]	140	<0.5	9	0.01	1.4	6.3	0.85	0.86	0.56	0.0	--	0.12	0.0	20	167	198	22	19	8.0	8.6
1650-W-Top	1	5	12	8.5	<10	42	2	0.00	730	50	110	<0.5	6	0.00	1.5	6.6	0.90	0.90	0.59	--	1	0.13	0.0	20	161	194	25	24	6.0	7.2
1650-C-Top	1	9	11	8.4	<10	45	5	0.00	800	120	140	<0.5	12	0.01	1.3	5.9	0.77	0.78	0.56	0.0	2	0.12	0.0	20	169	196	25	17	7.0	8.6
1650-E-Top	2	7	14	8.0	10	36	4	0.00	--	76	140	<0.5	11	0.02	1.4	6.2	0.83	0.85	0.56	0.0	0	0.12	0.0	70	162	188	24	27	9.0	8.4

Near Bottom

SAMPLING SITE \ PARAMETER	ARSENIC UG/L	CADMIUM UG/L	TOT ORG CARBON MG/L	CHLORIDE DISS MG/L	CHROMIUM TOT UG/L	COD HI LEVEL MG/L	COPPER UG/L	CYANIDE MG/L	IRON UG/L	LEAD UG/L	MANGANESE UG/L	MERCURY UG/L	NICKEL UG/L	NH_4 NITROGEN MG/L	TOT NITROGEN MG/L	NO_3 NITROGEN MG/L	TOT ORG NITROGEN MG/L	KJELDAHL NITROGEN MG/L	NO_2 and NO_3 MG/L	OIL and GREASE MG/L	PHENOLS MG/L	TOT ORTHO PHOS MG/L	SULFIDE MG/L	ZINC UG/L	RESIDUE DIS 180°C MG/L	RESIDUE TOT 105°C MG/L	RESIDUE SUSP 110°C MG/L	RESIDUE SUSP* 105°C MG/L	TURBIDITY NTU	TURBIDITY *
DP-1	2	11	12	8.4	10	50	6	0.00	4600	88	2000	<0.5	13	0.04	1.4	6.0	0.76	0.80	0.55	0.0	2	0.14	0.0	20	164	252	39	--	21	--
DP-2	2	13	15	8.1	10	43	6	0.00	6300	120	2500	<0.5	17	0.07	1.8	7.9	1.1	1.2	0.58	0.0	0	0.17	0.0	40	172	230	53	—	30	--
Cont-W-Bottom	2	8	14	8.3	<10	47	5	0.00	870	53	140	<0.5	11	0.01	1.4	6.1	0.80	0.81	0.57	0.0	3	0.12	0.0	20	167	196	21	12	8.0	8.6
Cont-E-Bottom	2	5	11	8.3	<10	49	4	0.00	800	36	130	<0.5	8	0.02	1.6	6.9	0.98	1.0	0.55	0.0	0	0.13	0.0	20	173	197	24	28	7.0	9.8

TABLE E-2 (Cont.)

Near Bottom 9-22-78

SAMPLING SITE / PARAMETER	ARSENIC UG/L	CADMIUM UG/L	TOT ORG CARBON MG/L	CHLORIDE DISS MG/L	CHROMIUM TOT UG/L	COD HI LEVEL MG/L	COPPER UG/L	CYANIDE MG/L	IRON UG/L	LEAD UG/L	MANGANESE UG/L	MERCURY UG/L	NICKEL UG/L	NH_4 NITROGEN MG/L	TOT NITROGEN MG/L	NO_3 NITROGEN MG/L	TOT ORG NITROGEN MG/L	KJELDAHL NITROGEN MG/L	NO_2 and NO_3 MG/L	OIL and GREASE MG/L	PHENOLS MG/L	TOT ORTHO PHOS MG/L	SULFIDE MG/L	ZINC UG/L	RESIDUE DIS 180°C MG/L	RESIDUE TOT 105°C MG/L	RESIDUE SUSP 110°C MG/L	RESIDUE SUSP 105°C MG/L	TURBIDITY NTU	[illegible]
BW-Bottom	2	11	11	8.1	10	45	4	0.00	740	110	130	<0.5	9	0.02	1.7	7.3	1.1	1.1	0.55	0.0	0	0.13	0.0	20	165	193	26	30	8.0	7.7
BE-Bottom	2	8	11	8.1	20	38	10	0.00	810	72	140	<0.5	10	0.02	1.4	6.1	0.80	0.82	0.55	0.0	3	0.13	0.0	40	171	198	23	13	8.0	8.7
100-W-Bottom	1	9	11	8.3	20	45	3	0.00	840	71	120	<0.5	10	0.01	1.5	6.8	0.99	1.0	0.54	--	3	0.13	0.0	20	166	198	21	24	8.0	10.1
100-C-Mid	2	11	12	8.4	<10	43	3	0.00	750	47	140	<0.5	11	0.01	1.4	6.2	0.85	0.86	0.55	--	0	0.12	0.0	20	172	193	21	37	8.0	8.7
100-E-Mid	2	14	13	8.2	10	41	3	0.00	1000	93	240	<0.5	7	0.03	1.3	5.9	0.75	0.78	0.55	0.0	0	0.12	0.0	20	177	190	19	23	8.0	8.8
200-W-Bottom	2	10	11	8.4	<10	47	3	0.00	830	63	110	<0.5	8	0.01	1.4	6.2	0.61	0.62	0.78	--	1	0.12	0.0	10	169	198	27	36	9.0	9.3
200-C-Mid	2	6	13	8.2	<10	40	3	0.00	730	31	140	<0.5	6	0.01	1.4	6.0	0.80	0.81	0.55	0.0	0	0.12	0.0	10	174	192	19	28	8.0	8.1
200-E-Mid	2	17	12	8.1	<10	53	3	0.00	1100	210	210	<0.5	7	0.02	1.5	6.5	0.89	0.91	0.56	0.0	1	0.12	0.0	20	166	189	19	26	8.0	7.7
300-W-Bottom	2	7	10	8.1	<10	38	4	0.00	1100	71	130	<0.5	6	0.01	1.2	5.3	0.64	0.65	0.55	--	0	0.11	0.0	20	173	198	15	26	8.0	8.2
300-C-Bottom	2	13	13	8.3	10	46	19	0.00	1000	74	130	<0.5	8	0.02	1.4	6.1	0.80	0.82	0.56	0.0	0	0.12	0.0	30	177	196	18	25	8.0	8.5
300-E-Bottom	2	13	15	8.3	10	51	3	0.00	1000	140	150	<0.5	7	0.03	1.7	7.3	1.1	1.1	0.56	0.0	0	0.12	0.0	20	131	199	21	24	9.0	8.4
400-W-Bottom	2	0	12	8.1	<10	40	3	0.00	840	15	130	<0.5	11	0.01	1.4	6.1	0.81	0.82	0.55	--	0	0.11	0.0	10	174	202	17	20	9.0	8.5
400-C-Bottom	2	8	11	8.3	<10	47	3	0.00	860	130	110	<0.5	10	0.01	1.4	6.4	0.89	0.90	0.54	0.0	1	0.12	0.0	20	167	201	25	35	8.0	10.8
400-E-Bottom	2	8	11	8.3	10	43	3	0.00	840	60	140	<0.5	9	0.02	1.7	7.3	1.1	1.1	0.56	0.0	0	0.12	0.0	20	175	198	23	25	8.0	9.2
950-W-Bottom	2	5	12	8.4	<10	42	2	0.00	810	39	130	<0.5	5	0.01	1.2	5.1	0.58	0.59	0.56	--	3	0.12	0.0	20	169	198	20	26	9.0	8.5
950-C-Bottom	2	15	11	8.2	<10	40	3	0.00	840	210	140	<0.5	9	0.01	1.6	7.1	0.99	1.0	0.61	--	2	0.12	0.0	20	172	201	28	23	7.0	8.2
950-E-Bottom	1	10	12	7.6	<10	42	10	0.00	880	85	140	<0.5	10	0.01	1.4	6.1	0.82	0.83	0.55	0.0	-	0.12	0.0	20	167	199	19	33	9.0	8.6
1650-W-Bottom	2	9	11	8.6	<10	45	3	0.00	740	76	110	<0.5	10	0.02	1.5	6.7	0.92	0.94	0.57	0.0	0	0.15	0.0	20	172	210	25	27	8.0	9.0
1650-C-Bottom	2	8	11	8.0	<10	44	4	0.00	790	58	140	<0.5	11	0.01	1.4	6.0	0.80	0.81	0.55	0.0	2	0.12	0.0	10	161	202	26	25	7.0	9.3
1650-E-Bottom	2	14	14	9.8	10	41	3	0.00	1100	98	140	<0.5	7	0.03	1.4	6.2	0.79	0.82	0.57	0.0	0	0.12	0.0	40	175	195	19	26	8.0	9.5

TABLE E-3 Comparison of Dissolved and Total Concentrations in Water for Selected Parameters and Sampling Sites at Wild's Bend Dredge Cut (9-19-78, 9-21-78, 9-22-78)

Date	Sampling Site / Parameter	Dis. Arsenic ug/1	Tot. Arsenic ug/1	Dis. Cadmium ug/1	Tot. Cadmium ug/1	Dis. Chromium ug/1	Tot. Chromium ug/1	Dis. Copper ug/1	Tot. Copper ug/1	Dis. Iron ug/1	Tot. Iron ug/1	Dis. Lead ug/1	Tot. Lead ug/1	Dis. Manganese ug/1	Tot. Manganese ug/1	Dis. Mercury ug/1	Tot. Mercury ug/1	Dis. Nickel ug/1	Tot. Nickel ug/1	Dis. KJD Nitro. mg/1	Tot. KJD Nitro. mg/1	Dis. Ortho Phosphorus mg/1	Tot. Ortho Phosphorus mg/1	Dis. Zinc ug/1	Tot. Zinc ug/1
-19-78	NBBC-Top	1	2	8	8	2	< 10	2	5	340	1100	70	70	10	140	<0.5	<0.5	2	31	0.68	0.84	0.08	0.11	10	50
-19-78	NBBC-Bottom	2	2	7	13	1	< 10	2	3	240	760	70	96	20	110	<0.5	<0.5	2	23	0.61	0.80	0.10	0.11	10	50
-21-78	Cont-c-Top	1	2	8	11	1	10	1	5	170	1000	95	95	10	130	<0.5	<0.5	2	9	0.54	0.59	0.12	0.13	10	30
-21-78	Cont-c-Bottom	1	2	5	7	0	< 10	1	4	170	780	52	63	20	120	<0.5	<0.5	0	8	0.61	0.61	0.12	0.13	10	20
-22-78	Cont-w-Top	1	2	8	11	1	< 10	1	6	200	820	56	92	30	130	<0.5	<0.5	1	16	0.87	0.87	0.12	0.12	0	20
-22-78	Cont-w-Bottom	1	2	7	8	2	< 10	2	5	210	870	48	53	30	140	<0.5	<0.5	1	11	0.81	0.81	0.12	0.12	0	20
-22-78	DP-1	1	2	6	11	1	10	1	6	120	4600	47	88	30	2000	<0.5	<0.5	1	13	0.78	0.80	0.08	0.14	10	20
9-22-78	DP-2	2	2	9	13	1	10	2	6	230	6300	69	120	70	2500	<0.5	<0.5	2	17	0.63	1.20	0.09	0.17	10	40
9-22-78	950-c-Top	1	1	9	15	1	10	2	3	200	880	72	150	40	140	<0.5	<0.5	1	9	0.91	0.86	0.12	0.12	10	20
9-22-78	950-c-Bottom	1	1	7	10	1	< 10	7	10	180	840	58	85	40	140	<0.5	<0.5	1	10	0.58	0.83	0.11	0.12	10	20
9-22-78	1650-c-Top	1	2	8	9	0	10	1	5	190	800	73	120	30	140	<0.5	<0.5	1	12	0.78	0.78	0.12	0.12	10	20
9-22-78	1650-c-Bottom	1	2	8	8	2	< 10	1	4	170	790	58	58	30	140	<0.5	<0.5	0	11	0.81	0.81	0.12	0.12	10	10

[illegible]PENDIX F BOTTOM SEDIMENT DATA

[illegible] F-1 1978 Bottom Sediment Reconnaissance - Settleability Tests (4:1 Mixture of Water and Sediment) - Conducted by MRD, Omaha, Nebraska.
[illegible] (PTO)

[illegible] RIVER MILE, DATE			ARSENIC ug/g	BARIUM ug/g	CADMIUM ug/g	CHROMIUM TOT ug/g	COD mg/kg	COPPER ug/g	CYANIDE ug/g	IRON ug/g	LEAD ug/g	MANGANESE ug/g	MERCURY ug/g	KJELDAHL NITROGEN mg/kg	NH4 NITROGEN ug/g	NICKEL ug/g	PHOSPHORUS TOTAL ug/g	RESIDUE (LOI) ms:kg	ZINC ug/g
[illegible]	[illegible].2	08-02-78	0	20	< 10	< 10	4,900	< 10	0	3,100	20	150	0.00	410	1.2	20	87	5,530	20
[illegible]	850.2	08-02-78	3	210	< 10	30	26,000	100	0	8,000	320	690	1.40	9,200	130	40	990	123,000	400
[illegible]	840.7	08-01-78	0	20	< 10	< 10	2,900	< 10	0	3,400	< 10	210	0.00	330	0.2	< 10	470	6,920	10
[illegible]	840.7	08-01-78	0	20	< 10	< 10	4,400	< 10	0	3,500	< 10	210	0.00	330	2.3	< 10	160	5,460	10
[illegible]	856.2	08-02-78	0	10	< 10	< 10	22,000	< 10	0	2,100	< 10	170	0.00	400	0.7	10	100	4,630	10
[illegible]	856.2	08-02-78	0	10	< 10	< 10	2,200	< 10	0	2,400	< 10	180	0.00	240	1.7	< 10	50	3,320	10
[illegible]	848.0	08-02-78	0	10	< 10	< 10	5,200	< 10	0	2,200	10	140	0.00	630	2.4	10	88	5,640	20
[illegible]	848.0	08-02-78	0	< 10	< 10	< 10	4,900	< 10	0	2,200	10	140	0.00	490	2.5	< 10	150	5,690	20
[illegible]	848.7	08-02-78	0	20	< 10	< 10	3,600	< 10	0	2,300	20	130	0.00	380	1.8	< 10	82	4,750	20
[illegible]	848.7	08-02-78	0	< 10	< 10	< 10	2,300	< 10	0	1,700	10	100	0.00	250	1.1	< 10	630	3,750	10
[illegible]	837.2	08-01-78	0	10	< 10	< 10	3,500	< 10	0	2,600	10	130	0.00	230	6.6	< 10	100	6,120	10
[illegible]	837.2	08-01-78	2	100	< 10	10	73,000	20	1	12,000	60	1,300	0.00	7,300	160	30	960	70,600	70
[illegible]	839.0	08-01-78	0	10	< 10	< 10	3,500	< 10	1	4,000	40	290	0.00	250	0.6	10	370	6,060	20
[illegible]	839.0	08-01-78	2	140	< 10	10	66,000	20	1	14,000	60	1,900	0.00	9,800	490	20	1,100	68,900	80
IICC2	839.0	10-05-78	0	30	< 10	< 10	3,300	10	0	3,700	30	140	0.00	300	8.7	30	140	3,940	68
[illegible]	823.2	08-03-78	0	< 10	< 10	< 10	4,300	< 10	0	2,600	< 10	120	0.00	450	3.0	< 10	190	6,720	20
[illegible]	823.2	08-03-78	0	10	< 10	< 10	5,600	< 10	0	3,400	< 10	130	0.00	520	2.6	< 10	88	4,900	20
[illegible]	827.9	08-03-78	0	< 10	< 10	< 10	2,800	< 10	0	1,700	< 10	100	0.00	302	1.4	< 10	97	5,290	8.0
[illegible]E2	827.9	08-03-78	0	10	< 10	< 10	1,900	< 10	0	3,000	< 10	170	0.06	350	1.7	< 10	85	5,560	20
IIF1	784.6	08-16-78	0	< 10	< 10	10	2,800	< 10	0	2,200	< 10	130	1.4	410	1.1	< 10	93	1,120	< 10
IIF2	784.6	08-16-78	0	30	< 10	< 10	15,000	< 10	0	3,600	20	290	2.2	1,200	3.8	< 10	430	4,080	18
IIIC1	811.0	08-04-78	0	10	< 10	< 10	2,800	< 10	0	3,000	< 10	340	0.00	220	2.2	< 10	270	7,210	10
III[illegible]2	811.0	08-04-78	0	20	< 10	< 10	1,900	< 10	0	3,200	< 10	180	0.00	240	1.4	< 10	46	3,660	10
[illegible]	801.9	08-04-78	0	20	< 10	< 10	2,200	< 10	0	2,300	< 10	160	0.04	260	1.4	< 10	260	5,680	10
[illegible]	801.9	08-04-78	0	10	< 10	< 10	2,200	< 10	0	3,700	< 10	160	0.00	300	2.2	< 10	110	5,790	20
[illegible]	807.8	08-04-78	0	30	< 10	< 10	1,600	< 10	0	5,000	< 10	450	0.00	190	1.5	< 10	440	4,700	20
IIIE2	807.8	08-04-78	0	< 10	< 10	< 10	1,800	< 10	0	2,400	< 10	200	0.00	280	0.9	< 10	170	3,750	10
[illegible]	792.8	08-16-78	0	10	< 10	< 10	2,400	< 10	0	2,400	< 10	180	0.66	390	8.5	< 10	80	681	10
[illegible]	792.8	08-16-78	0	< 10	< 10	< 10	1,800	< 10	0	1,700	< 10	970	0.47	200	0.9	< 10	37	770	< 10
[illegible]	759.0	08-16-78	0	30	< 10	20	1,700	< 10	0	2,400	< 10	310	0.00	250	0.5	< 10	240	1,450	10
[illegible]	759.0	08-16-78	0	30	< 10	< 10	1,600	< 10	0	2,700	< 10	260	0.00	130	0.5	< 10	67	1,820	10
[illegible]	757.5	08-16-78	0	30	< 10	< 10	2,800	< 10	0	2,300	< 10	250	0.00	200	0.7	< 10	35	1,190	10
[illegible]	757.5	08-16-78	0	30	< 10	< 10	2,200	< 10	0	1,900	< 10	250	0.00	260	0.7	< 10	140	1,020	10
[illegible]	[illegible]4.2	08-16-78	0	10	< 10	< 10	2,000	< 10	0	2,200	< 10	130	0.00	170	1.2	< 10	35	2,620	10
[illegible]	[illegible].2	08-16-78	0	10	< 10	< 10	1,800	< 10	0	2,000	< 10	180	0.00	220	0.4	< 10	180	870	12
[illegible]	[illegible]31.5	08-17-78	0	60	< 10	< 10	1,800	< 10	0	2,600	< 10	500	0.34	410	0.5	< 10	680	1,130	10
[illegible]D1	[illegible]32.5	10-04-78	0	90	< 10	< 10	2,100	< 10	0	2,900	< 100	780	0.00	270	2.2	< 100	110	3,770	15
[illegible]	[illegible]31.5	08-17-78	0	40	< 10	< 10	1,700	< 10	0	3,200	< 10	490	0.70	220	0.8	< 10	960	1,260	10
[illegible]	731.5	10-04-78	0	40	< 10	< 10	2,300	< 10	0	1,900	< 100	330	0.00	120	1.1	20	240	2,830	15
[illegible]	[illegible]41.8	08-16-78	0	30	< 10	< 10	8,100	< 10	0	3,200	< 10	270	0.75	1,000	3.4	< 10	100	2,970	< 10
[illegible]2*	[illegible]41.8	08-16-78	--	-	-	-	--	-	--	--	-	--	--	--	--	-	--	--	-
[illegible]	[illegible]41.8	10-04-78	0	10	< 10	< 10	2,000	< 10	0	1,800	< 100	170	0.00	490	1.5	20	150	3,070	4.0
[illegible]	[illegible]33.6	08-17-78	0	30	< 10	< 10	1,300	< 10	0	2,200	< 10	310	0.16	210	0.7	< 10	42	1,680	< 10
[illegible]	[illegible]33.6	08-17-78	0	30	< 10	< 10	1,600	< 10	0	1,900	< 10	240	0.08	180	0.8	< 10	85	1,260	< 10
[illegible]	[illegible]90.0	09-27-78	0	10	< 10	< 10	2,400	< 10	0	1,500	< 100	270	0.08	83	0.8	< 100	58	3,020	< 10
[illegible]	[illegible].0	09-27-78	0	< 10	< 10	< 10	2,200	< 10	0	1,200	20	93	0.00	79	0.7	< 100	60	2,080	< 10
VB[illegible]	664.3	09-27-78	0	40	< 10	< 10	2,400	< 10	0	2,300	20	470	0.00	40	0.8	< 100	14	2,900	< 10
VB[illegible]*	664.3	09-27-78	--	-	-	-	--	-	--	--	-	--	--	--	--	-	--	--	-
[illegible]	708.5	08-17-78	0	10	< 10	< 10	1,200	< 10	0	2,500	< 10	24	0.00	210	0.7	< 10	190	5,750	10
VC2	708.5	08-17-78	0	30	< 10	< 10	1,800	< 10	0	2,200	10	29	0.00	180	1.0	< 10	180	6,680	10
[illegible]	665.4	09-27-78	0	< 10	< 10	< 10	120	< 10	0	1,800	20	260	0.00	66	0.7	< 100	18	2,500	< 10
[illegible]	665.4	09-27-78	1	10	< 10	< 10	2,700	< 10	0	1,900	20	240	0.04	22	0.9	< 100	170	2,400	< 10
[illegible]	721.0	08-17-78	0	10	< 10	< 10	2,100	< 10	0	1,900	30	35	0.00	800	1.0	< 10	74	4,120	10
[illegible]	721.0	08-17-78	0	30	< 10	< 10	1,800	< 10	0	2,200	< 10	42	0.00	240	1.1	< 10	230	5,750	10
VF1	677.9	08-18-78	0	10	< 10	30	2,000	< 10	0	2,000	< 10	22	0.00	420	1.0	< 10	380	5,840	< 10
[illegible]	677.9	08-18-78	0	20	< 10	< 10	1,300	< 10	0	1,600	< 10	12	0.00	190	1.3	< 10	110	4,500	< 10

*Samples not received or [illegible] in shipment.

Table F-1 (Cont.)

SITE NAME	RIVER MILE	ALDRIN ug/kg	CHLORDANE ug/kg	DDD ug/kg	DDE ug/kg	DDT ug/kg	DIELDRIN ug/kg	ENDOSULFAN ug/kg	ENDRIN ug/kg	HEPTACHEPOXIDE ug/kg	HEPTACHLOR ug/kg	LINDANE ug/kg	MIREX ug/kg	OIL & GREASE ug/kg	PCB ug/kg	PCN ug/kg	PERTHANE ug/kg	TOXAPHENE ug/kg
IA1	850.2	0.0	0	1.2	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	4	0	0.0	0
IA2	850.2	0.0	0	0.0	49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1000	32	0	0.0	0
IB1	840.7	0.0	0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IB2	840.7	0.0	0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	5	0	0.0	0
IC1	856.2	0.0	0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IC2	856.2	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	0	0	0.0	0
ID1	848.0	0.0	0	3.6	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	5	0	0.0	0
ID2	848.0	0.0	0	0.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	3	0	0.0	0
IE1	848.7	0.0	2	2.2	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	6	0	0.0	0
IE2	848.7	0.0	0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1	0	0.0	0
IIA1	837.2	0.0	1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	11	0	0.0	0
IIA2	837.2	0.0	9	3.8	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0	200	0	0.0	0
IIC1	839.0	0.0	0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	10	0	0.0	0
IIC2	839.0	0.0	4	2.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	66	0	0.0	0
IICC2	839.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IID1	823.2	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	8	0	0.0	0
IID2	823.2	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IIE1	827.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IIE2	827.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IIF1*	784.6	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
IIF2	784.6	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	1	0	0.0	0
IIIC1	811.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IIIC2	811.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IIID1	801.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IIID2	801.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IIIE1	807.8	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	0	0	0.0	0
IIIE2	807.8	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IIIF1	792.8	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	0	0	0.0	0
IIIF2	792.8	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVA1	759.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVA2	759.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVB1	757.5	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVB2	757.5	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVC1	754.2	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVC2	754.2	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVD1	731.5	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVDD1	731.5	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVD2*	731.5	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
IVDD2	731.5	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVE1	741.8	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	6	0	0.0	0
IVE2	741.8	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVEE2	741.8	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVF1	733.6	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
IVF2	733.6	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	0	0	0.0	0
VA1	690.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VA2	690.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VB1	664.3	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VB2	664.3	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VC1	708.5	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VC2	708.5	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VD1	665.4	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VD2*	665.4	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
VE1	721.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VE2	721.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VF1	677.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0
VF2	677.9	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0.0	0

*Samples not received or lost in shipment.

TABLE F-2
1978 Bottom Sediment Reconnaissance - Settleability Tests (4:1 Mixture of Water and Sediment) - Conducted by MRD, Omaha, Nebraska. Suspended Solids (mg/1).

Sampling Sites/		Hours After Agitation													
River Mile		0	2	4	6	24	48	72	96	120	144	164	192	216	264
IA1	850.2	336	136				32								
IA2	850.2	18032				92	132		116				32		
IB1	840.7	504	156	104	108	84	0								
IB2	840.7	24720	288	220	172	84	12								
IC1	856.2	272	48	20	60	48	32								
IC2	856.2	152	28	16	12	40	14								
ID1	848.0	2584	296	212	136	72	44		32						
ID2	848.0	944	160	10	124	60	0								
IE1	848.7	1184	1280	68	84	48	0								
IE2	848.7	236	36	24	36	16	0								
IIA1	837.2	2052	144	124		8									
IIA2	837.2	189804	11484			324		416	340				440	476	
IIC1	839.0	572	148	128		48		36	8						
IIC2	839.0	178412	332	324		200		128	84				120	180	
IID1	823.2	1925	224	224		96		12							
IID2	823.2	6996	492	348		172		52	28						
IIE1	827.9	724	60	56		32									
IIF1	784.6	716	96	100		12									
IIF2	784.6	29720	356	228		96		0							
IIIC1	811.0	532	120	80	16										
IIIC2	811.0	228	108	60	44	24									
IIID1	801.9	96	0	36	8										
IIID2	801.9	284	72	60	28										
IIIE1	807.8	136	36	44	28										
IIIE2	807.8	144	60	40	32	28									
IIIF1	792.8	244	88	60	84	68		0							
IIIF2	733.6	476	120	88	100	56		12							
IVA1	759.0	112	84	0											
IVA2	759.0	88	88	16											
IVB1	757.5	92	68	48		4									
IVB2	757.5	144	72	0											
IVC1	754.2	596	56	4											
IVC2	754.2	276	40	0											
IVD1	731.5	196	88	120		8									
IVDD1	731.5	204	60	0	0										
IVD2	731.5	224	72	80		0									
IVDD2	731.5	64	0	0											
IVE1	741.8	18916	676	404		44			72		52		40		0
IVE2	741.8	1204	0	96		20									
IVEE2	741.8	1760	156	0	60	16									
IVF1	733.6	236	0	0											
IVF2	733.6	284	24	0											
VA1	690.3	180	76	0											
VA2	690.3	340	116	0											
VB1	664.3	332	116	12											
VB2	664.3	1708	252	88	124	56	36			4					
VC1	708.5	324	80	40	80	52	36			0					
VC2	708.5	700	112	72	100	64	40			0					
VD1	665.4	264	8	12											
VD2	665.4	268	24	20											
VE1	720.8	612	68	48	116	96	0								
VE2	720.8	132	48	76		124				0					
VF1	677.9	280	44	88		108				0					
VF2	677.9	804	172	124		116									

TABLE F-3

1978 Bottom Sediment Reconnaissance - Settleability Tests (4:1 Mixture of Water and Sediment) - Conducted by MRD, Omaha, Nebraska. Turbidity (FTU)

Sampling Sites/	River Mile	Hours After Agitation													
		0	2	4	6	24	48	72	96	120	144	164	192	216	264
IA1	850.2	84	48			18	13								
IA2	850.2	20,000				68	52		62				33		
IB1	840.7	128	66	48	39	19	68								
IB2	840.7	620	156	132	112	36	11								
IC1	856.2	66	28	22	20	10	3								
IC2	856.2	42	23	19	18	11	5.5								
ID1	848.0	730	205	155	130	52	14		8						
ID2	848.0	270	112	80	76	40	7.5								
IE1	848.7	310	84	58	54	30	6.6								
IE2	848.7	74	30	25	25	15	6.6								
IIA1	837.2	418	160	80		25									
IIA2	837.2	45,000	2,800			11		15	12				16	11	
IIC1	839.0	250	100	70		34		16	15						
IIC2	839.0	45,000	280	156		120		40	30				16	6	
IID1	823.2	600	152	180		82		20							
IID2	823.2	2,600	350	340		129		41	31						
IIE1	827.9	210	60	43		28		14							
IIF1	784.6	230	112	64		34		15							
IIF2	784.6	11,000	310	220		52		20							
IIIC1	811.0	190	70	44	37										
IIIC2	811.0	52	41	27	24	25									
IIID1	801.9	33	31	16	15										
IIID2	801.9	48	40	27	25										
IIIE1	807.8	31	20	14	12										
IIIE2	807.8	34	24	15	12	10									
IIIF1	792.8	82	50	30	27	29		11							
IIIF2	733.6	290	124	70	60	42		21							
IVA1	759.0	20	12	20											
IVA2	759.0	16	10	10											
IVB1	757.5	14	17	10		13									
IVB2	757.5	23	14	12											
IVC1	754.5	140	34	31											
IVC2	754.2	32	31	20											
IVD1	731.5	20	16	16		12									
IVDD1	731.5	52	34	22	28										
IVD2	731.5	25	28	17		12									
IVDD2	731.5	29	17	14											
IVE1	741.8	4,000	580	320		60			47		26		21		11
IVE2	741.8	192	136	82		33									
IVEE2	741.8	280	80	60	62	21									
IVF1	733.6	28	32	28											
IVF2	733.6	68	31	25											
VA1	690.3	48	30	26											
VA2	690.3	82	41	30											
VB1	664.3	60	32	26											
VB2	664.3	310	100	30	30	29	19				11				
VC1	708.5	70	31	27	31	18	13				7.6				
VC2	708.5	150	42	36	44	26	16				13				
VD1	665.4	43	25	21											
VD2	665.4	50	31	28											
VE1	720.8	152	60	40	50	27	17								
VE2	720.8	33	24	20		19				11					
VF1	677.9	54	25	21		20				10					
VF2	677.9	136	58	36		24				11					

Table F-4 1978 Bottom Sediment Reconnaissance Particle Size
(Conducted by MRD, Omaha, Nebraska)

SEDIMENT CLASSIFICATION RECORD

SAMPLE I.D. NUMBER & RIVER MILE		GRADING (CUMULATIVE PERCENTS FINER)											
		HYD. ANALYSIS			U.S. STANDARD SIEVE SIZES								
		FINES			SAND					GRAVEL			
		.005	.02mm	.200mm	60	40	20	10	4	3/8	3/4	1 1/2	3 in.
IA1	850.2	0	0.5	2	3	33	86	98	100				
IA2	850.2	13	35	68	79	90	[illegible]	97	99	100			
IB1	840.7	0	0	3	4	7	15	34	60	79	100		
IB2	840.7	0	0.5	3	7	35	75	95	99	100			
IC1	856.2	0	0	4	6	39	46	59	68	78	95	100	
IC2	856.2	0	0.5	3	5	37	59	98	99	100			
ID1	848.0	0	1	5	25	93	95	99	100				
ID2	848.0	0	0	3	20	100							
IE1	848.7	0	0	3	7	63	91	99	100				
IE2	648.7	0	0	1	11	94	100						
IIA1	837.2	0	0	4	9	34	90	100					
IIA2	837.2	22	45	83	94	100							
IIC1	839.0	0	0	3	4	5	9	27	63	83	98	100	
IIC2	839.0	25	48	63	72	77	87	95	100				
IICC2	839.0	0	1	5	15	33	92	99	100				
IID1	823.2	0	0	3	11	91	100						
IID2	823.2	0	0	6	13	83	99	100					
IIE1	827.9	0	0	2	3	34	84	96	100				
IIF1	784.6	0	0	1	3	41	90	99	100				
IIF2	784.5	2	8	22	67	99	100						
IIIC1	811.0	0	1	3	5	11	22	49	90	100			
IIIC2	811.0	0	0	0	1	34	92	99	100				
IIID1	801.9	0	0	1	2	49	84	97	100				
IIID2	801.9	0	0	0	1	59	91	99	100				
IIIE1	807.8	0	0	2	3	31	74	90	96	100			
IIIE2	807.8	0	0	0	2	59	95	99	100				
IIIF1	792.8	0	1	1	5	58	88	98	100				
IIIF2	792.8	0	1	2	8	69	97	100					
IVA1	759.0	0	0	1	2	27	66	87	95	100			
IVA2	759.0	0	0	1	2	30	76	96	100				
IVB1	757.5	0	0	0	3	35	73	90	99	100			
IVB2	757.5	0	0	1	2	44	83	96	98	100			
IVC1	754.2	0	0	1	2	46	95	100					
IVC2	754.2	0	0	0	3	59	93	99	100				
IVD1	731.5	0	0	1	3	28	61	85	97	100			
IVDD1	731.5	0	1	1	3	22	68	96	100				
IVD2	731.5	0	1	2	3	22	71	93	98	100			
IVDD2	731.5	0	0	1	1	52	95	99	100				
IVE1	741.8	0	2	8	10	41	80	93	97	100			
IVE2	741.8	0	0	1	4	64	95	100					
IVEE2	741.8	0	0	1	5	72	94	97	97	98	100		
IVF1	733.6	0	0	2	4	55	84	95	100				
IVF2	733.6	0	0	1	3	22	68	96	100				
VA1	690.3	0	0	5	5	48	88	98	100				
VA2	690.3	0	0	0	3	84	99	100					
VB1	664.3	0	0	1	6	78	97	100					
VB2	664.3	0	1	3	20	94	100						
VC1	708.5	0	0	0	2	36	85	98	100				
VC2	708.5	0	0	1	5	53	87	98	100				
VD1	665.4	0	0	0	2	66	97	100					
VD2	665.4	0	0	1	5	84	99	100					
VE1	720.8	0	0	1	2	55	94	100					
VE2	720.8	0	0	1	3	51	94	100					
VF1	677.9	0	0	1	3	52	93	99	100				
VF2	677.9	0	0	8	89	100							

DREDGED MATERIAL
DISPOSAL APPENDIX

APPENDIX G
DREDGED MATERIAL DISPOSAL STUDY

Purpose and Study Site

Sedimentation is a natural process on the Mississippi River. During high flow, sediment is picked up and deposited as the water velocity decreases. Usually the deposition is thin, averaging a few inches or more, and occurring in the spring of the year. Due to increasing concern and requirements for disposal of dredged material on land, it is important to determine the effects of placing an unnatural amount of sediment, up to several feet in depth, on existing vegetation throughout the year.

In October of 1978, a study was initiated to monitor the effects of dredged material deposition on the health and longevity of an inland floodplain forest. The study location selected was Dresbach Island near Dresbach, Minnesota (Figure 1). Historically, the Corps has used this island as a disposal site for dredged material. Due to time constraints the study is limited to the impact of dredged material placement on the overstory vegetation.

The floodplain forest on the island is typical of the vegetation found throughout the floodplain of the Upper Mississippi River. The overstory consists of elm (Ulmus americana), cottonwood (Populus deltoides), black willow (Salix nigra), green ash (Fraxinus pennsylvanica), boxelder (Acer negundo), silver maple (Acer saccharinum), and river birch (Betula nigra). The understory vegetation is typical of floodplain islands. The sparse ground cover is dominated by nettle (Urtica dioica) and poison ivy (Rhus radicans).

Two 100 x 100-foot plots were selected within the dredged material disposal site. One plot is on the periphery of the area and is expected to receive very little if any dredged material and therefore was used as a control. (See Figure 2.) The area is a confined disposal site and therefore is surrounded by a berm about 3 feet high.

All trees greater than 4 inches in diameter were recorded by species, tree condition, and diameter (d.b.h.) and marked with a nail 9 feet above the ground surface to determine the depth of fill material. Table 1 summarizes the tree data.

Results

The disposal area was utilized in the fall of 1978. Due to the small amount of dredging that was needed in 1978, the depth of fill material was not as great as was anticipated (see Figure 3).

The study plots were revisited in August of 1979. Although a few trees were recorded as dead, the vast majority are in good or moderate condition. Some trees showed evidence of scarring and bark damage, probably caused by machinery used in dike construction and by campers and picnickers using the island.

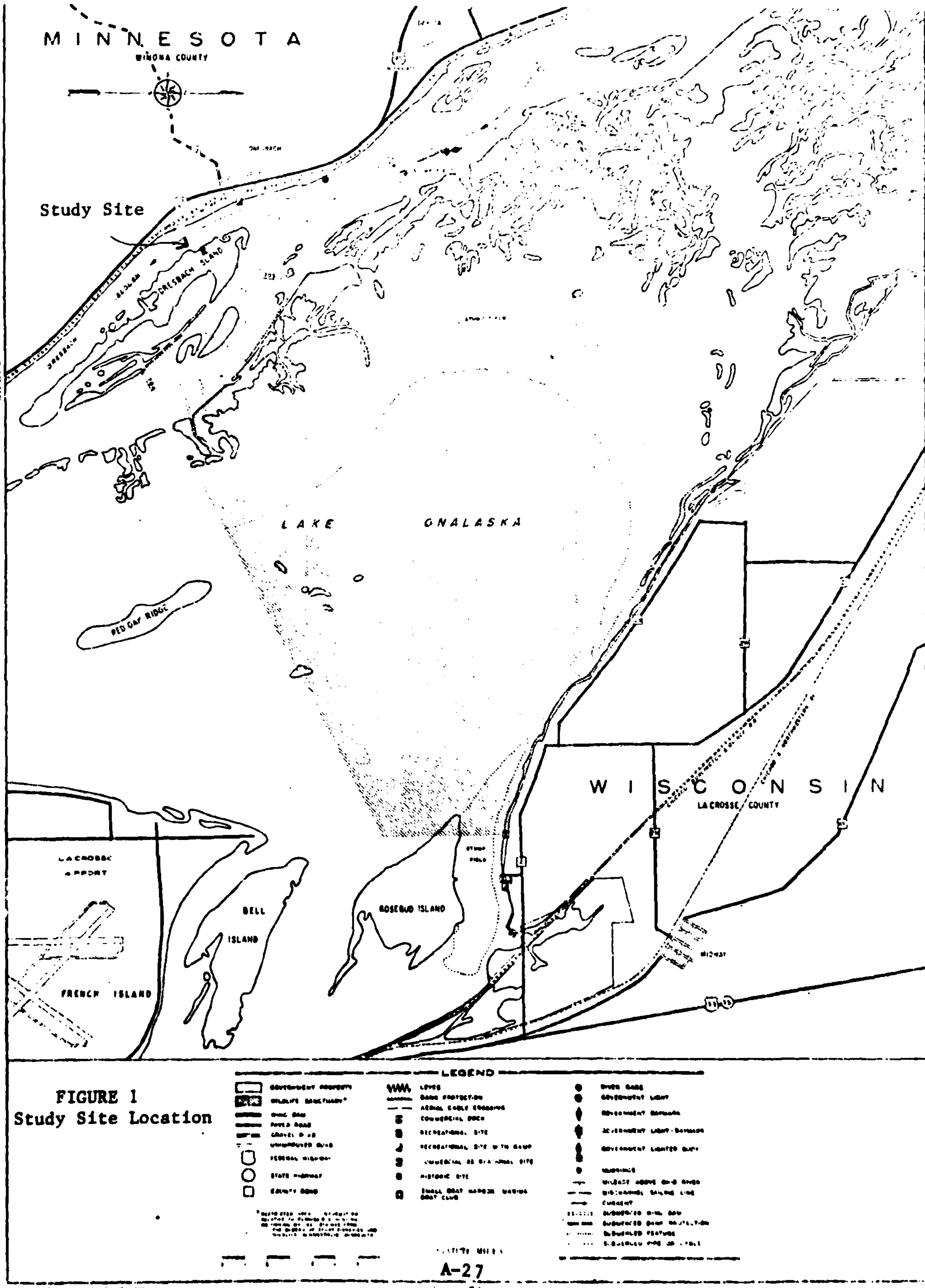


FIGURE 1
Study Site Location

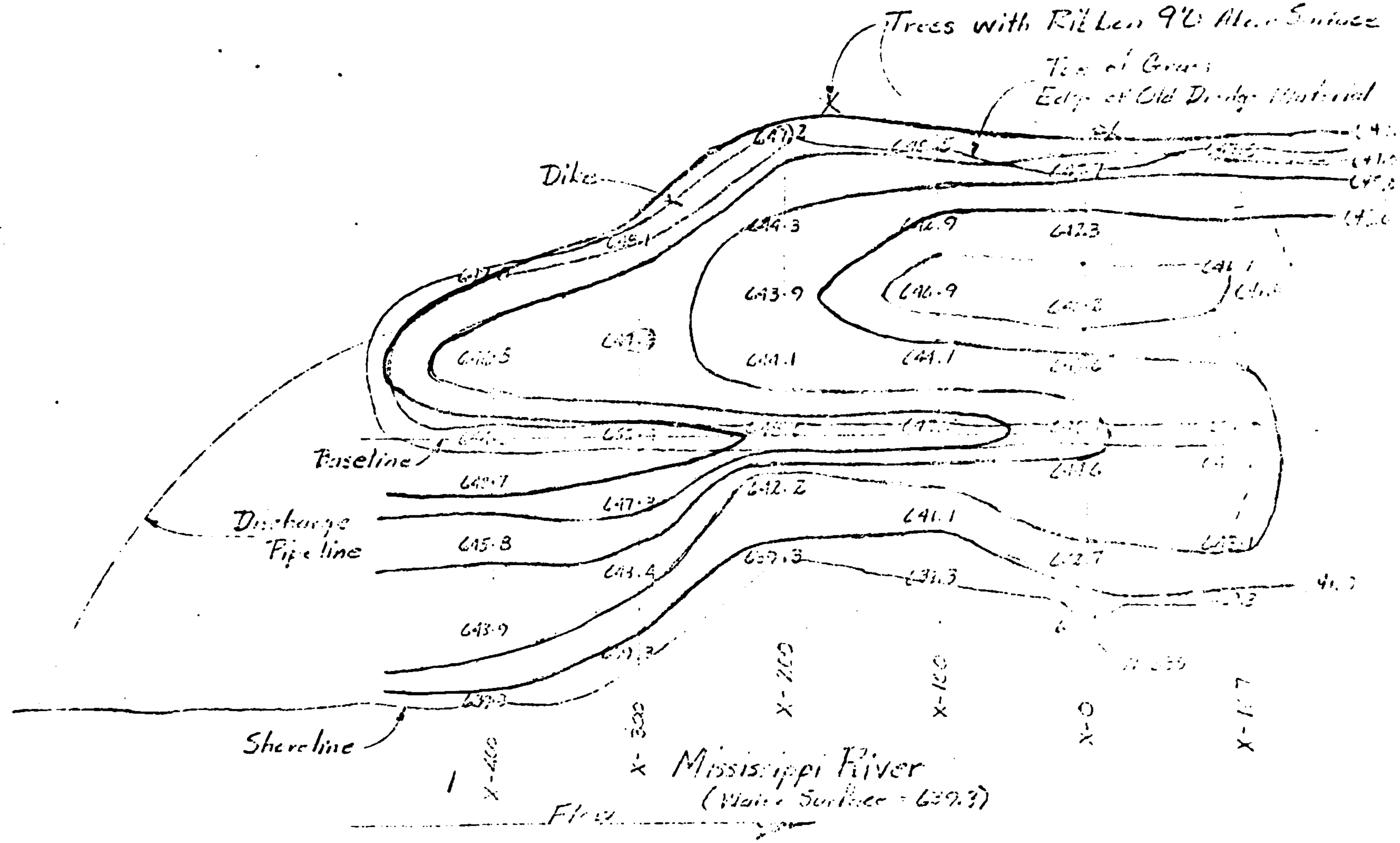


Figure 2

Dredge Material Placement Area
Dresbach, Minnesota Mile 703.0
Before Dredging 17 Nov 197
Scale 1" = 100'

Table 1 Summary of Tree Data by Species

Species	Total Number	Mean Diameter (in.)	Standard Deviation (in.)	Range (in.)
Plot No. 1				
Cottonwood	1	9.2		
Black Willow	6	16.5	3.8	11.4 - 20.7
Green Ash	7	5.5	.9	4.2 - 6.5
Elm	30	9.3	5.0	4.3 - 24.4
Boxelder	1	8.3		
Silver Maple	5	5.8	1.2	4.7 - 7.3
Total	50	9.3	5.1	4.2 - 24.4
Plot No. 2				
River Birch	6	10.2	2.6	7.7 - 14.8
Green Ash	18	6.6	1.5	4.4 - 9.3
Elm	33	7.0	2.0	4.2 - 11.8
Black Willow	2	18.9	6.2	14.5 - 23.3
Silver Maple	8	7.2	2.4	4.2 - 11
Mulberry	2	7.4	2.0	5.9 - 8.8
White Oak	3	8.9	4.3	6.1 - 13.9
Cottonwood	1	21.2		
Total	73	7.8	3.4	4.2 - 23.3

On plot 1, both sedimentation and erosion around the trees have occurred, due to the building of the dike and to erosion which was probably caused by the release of dredged material from the pipeline. On plot 2, where about one-third of the trees received no fill material, no erosion was evident. Table 2 summarizes the data on depth of fill material.

Table 2. Depth of Fill Material

	Mean (ft.) Depth	Standard Deviation (ft.)	Range (ft.)	n
Plot 1				
Fill	1.9	1.2	.3 to 6.3	39
Cut	-.8	.6	-.1 to -1.8	10
Plot 2				
Fill	2.3	1.0	.2 to 4.4	34

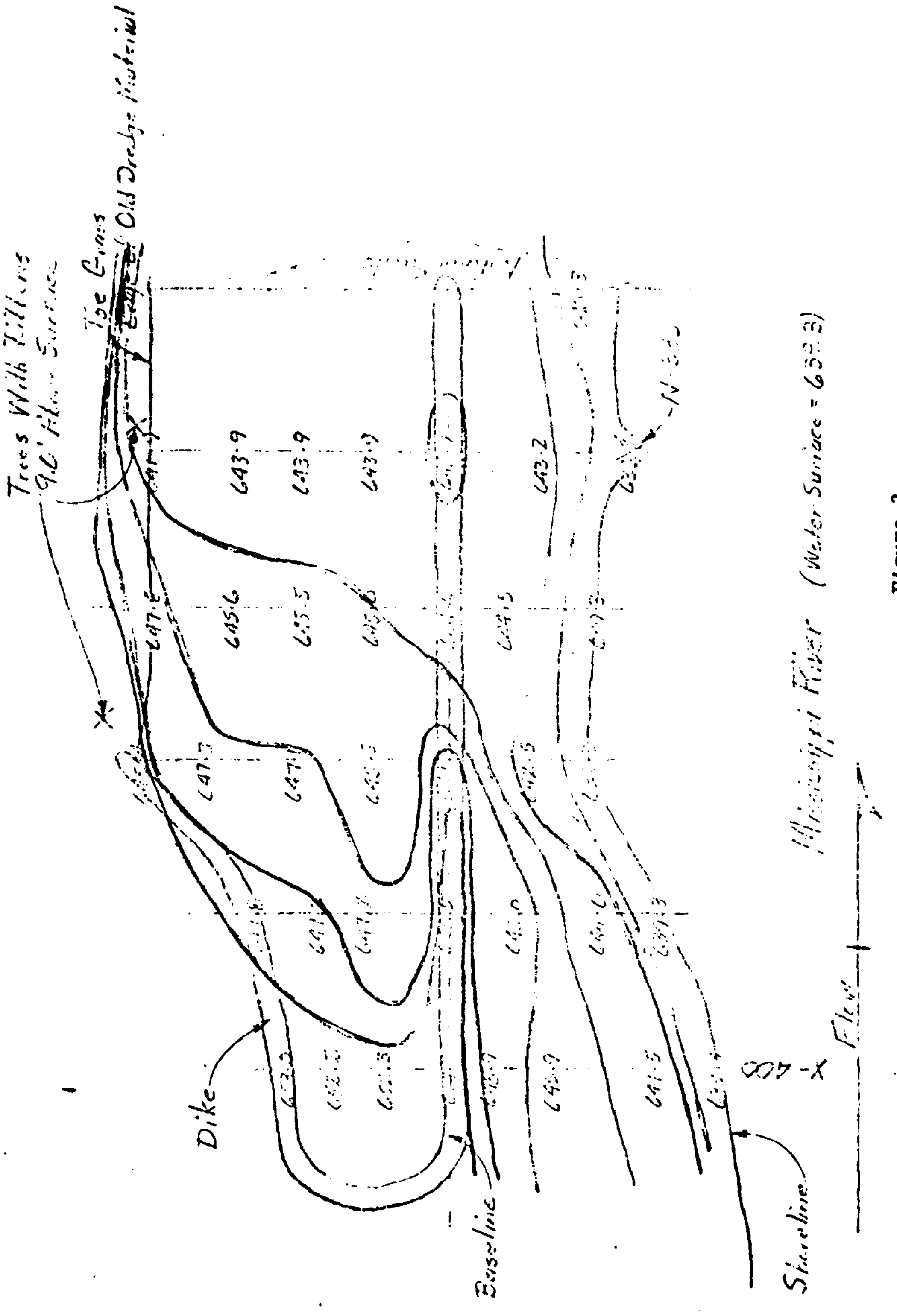


Figure 3
Dredge Material Placement and Areas
[illegible], Minnesota Mile [illegible]
After Dredging 20 Nov 1976
Scale 1" = 100

FIGURE 3

If future tree death does result, two factors other than the placement of the fill material should be considered as possible contributing causes:

1. The mechanical injury to the trees could increase the probability of insect and disease attack.

2. The dike may "pond" water longer than would occur naturally. If this ponding extended into the growing season, the stagnant water would create anaerobic conditions which could result in tree death.

Because the results of sedimentation may not appear for a number of years, the study should continue for a few more years to monitor survival. Future studies should also include growth rate studies to determine if sedimentation affects tree growth. This could be accomplished by increment borings or by taking cross-sections from the trees.

Discussion

The assessment of the health of the trees was originally conducted in October, during the dormant season, making it difficult to determine condition. A second assessment, made in August 1979, should be used as the base for making future comparisons since it will be the best indication of condition during the growing season. Most of the trees appear to be in good condition despite the fill material, possibly due to one or more of the following factors:

1. The trees may not show the effects of the fill activity for 2 or more years. Research has shown that trees may not succumb to temporary inundation for up to 4 years (Yeager 1949; Green 1947).

2. The fill material may not be of a depth great enough to kill the tree. The mean depth of fill is approximately 2 feet, while natural sedimentation may be up to 6 inches. Therefore, a greater depth may be needed to affect survival.

3. Fill activities may have no effect, since the trees are accustomed to some sediment being deposited around their bases as a result of natural flooding. Adventitious (appearing in an unusual or abnormal place) buds form on many of the floodplain species, thereby improving their chances of survival.

4. The fill material is sandy and therefore does not seal the soil surface, thereby restricting the movement of air and water, whereas fine-grained, compacted material would restrict the exchange of gases between the soil and atmosphere. Kennedy and Krinard (1974) found that in Mississippi, almost pure sand deposits up to 5-foot depths had no effect on trees 2 to 3 months after siltation occurred.

Bibliography

Green, W.E. 1947 "Effect of Water Impoundment on Tree Mortality and Growth." Journal of Forestry 45(2):118-120.

Kennedy, H.E. Jr. and R.M. Krinard - 1974. "1973 Mississippi River Flood's Impact on Natural Hardwood Forests and Plantations." U.S. Forest Service, Southern Forest Exp. Station. Res. Note SO-177.

Yeager, L.E. 1949. "Effect of Permanent Flooding in a River-bottom Timber Area." Bulletin of the Illinois Natural History Survey, Vol. 25, Art. 2, p. 33-65.

CONTRACTOR'S
APPENDIX

APPENDIX H

EFFICACY OF EFFLUENT CONTAINMENT AS A MEANS OF MINIMIZING ADVERSE MICROBIOLOGICAL WATER QUALITY EFFECTS OF HYDRAULIC DREDGING

A report to the St. Paul District of the U.S. Army Corps of Engineers in fulfillmnet of purchase order DACW37-78M-2578

by

D. Jay Grimes, Ph.D.
Associate Professor of Biology
River Studies Center
University of Wisconsin-La Crosse
La Crosse, WI 54601
March 1979

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

Special thanks are extended to Bruce Biltgen, Jan Claassen, and Kathy Trapp for their technical help in the field and in the laboratory. I am also thankful to Larry Trammell, Pat Burns, and Gary Lukes for help in media preparation and to Coline Atchison for manuscript typing and editing. This project was supported by a contract with the U.S. Army Corps of Engineers (P.O. No. DACW37-78M-2578).

ABSTRACT

The microbiological water quality effects of hydraulic dredging with effluent containment were investigated. Microbiological water quality was assessed by performing total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) density determinations and by enriching for salmonellae and shigellae. Sediment in the area to be dredged was also analyzed for TC, FC, and FS densities and for salmonellae and shigellae. The sediment was composed of coarse sand, and was found to contain very low densities of indicator bacteria (mean MPN indeces, per gram dry wt, were 11 TC's, 3 FC's, and 1 FS); no salmonellae or shigellae were recovered from the sediment samples. There were no significant differences (F-values all below the critical level for rejection of the null hypothesis) between indicator bacteria concentrations in the sample groups (i.e., control water samples, water samples downstream to the dredge cutterhead, and water samples downstream to the effluent containment pit), and the majority of salmonellae (76%) were isolated from control water samples. Because of the absence of fecal bacteria (indicators and pathogens) in the sediment, the data could not be used to support (or reject) effluent containment as a means of minimizing adverse microbiological water quality effects of hydraulic dredging.

INTRODUCTION

Microbiological effects of dredging in the Upper Mississippi River have been partially investigated (5,6,7). In 1976, water samples collected downstream from the discharge of hydraulically dredged, contaminated material were found to contain significantly greater quantities of total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) bacteria and turbidity than upstream controls (6). In 1977, water samples collected during a clamshell dredging operation revealed that this type of dredging had no significant effect on microbiological water quality as measured by TC, FC, and FS bacteria (7). It was suggested that the relatively passive nature of clamshell dredging was largely responsible for observed differences.

Hydraulic dredging is now the most efficient method for removing large volumes of unwanted sediment from the main channel of the Mississippi River. Accordingly, ways to minimize adverse effects of hydraulic dredging on water quality are being investigated. One promising method is on-land disposal with containment of the dredged material. Containment does not stop, or in any way reduce, sediment disturbance at the dredge cutterhead. It does, however, prevent much of the water in the dredged material slurry from directly reentering the river. It is this carrier water that contains the greatest burden of contaminants, including bacteria (7), and any procedure that prevents this water from directly reentering the river should greatly reduce dredge-associated pollution.

In September 1978, a research project designed to evaluate dredged material containment was executed by the St. Paul District of the

U.S. Army Corps of Engineers. One particular objective of this project was to determine what microbiological changes occurred in the water column as a result of hydraulic dredging and disposal of dredge effluent in an onshore containment pit. This objective was the basis of a contract awarded to this author, and specific microbiological effects under investigation were as follows:

1. To determine the numbers of TC, FC, and FS bacteria residing in the bottom sediments of the area to be dredged.
2. To determine the contribution of dredge cutterhead disturbance in resuspending TC, FC, and FS bacteria in the water column.
3. To determine the ability of a containment structure to minimize the impact of hydraulic dredge effluent on river water quality as measured by TC, FC, and FS bacteria.
4. To determine the presence of salmonellae and shigellae in all samples tested.

MATERIALS AND METHODS

Study site. Dredging was conducted by the hydraulic dredge William A. Thompson in the Wild's Bend reach of Navigation Pool 5A of the Upper Mississippi River. The dredge cut extended from river mile 730.3 to 730.7 (Fig. 1) and the dredging was accomplished between 21 and 22 September 1978.

Sampling techniques. Water samples were collected by means of van Dorn bottles; 2.5 to 3.0 l of each sample were transferred to a sterile 1-gal polypropylene milk bottle for transportation to our laboratory. Sediment samples were collected by Ponar dredge and were placed in Whirl-Pak bags for shipment. All samples were iced in transit and were then stored in a

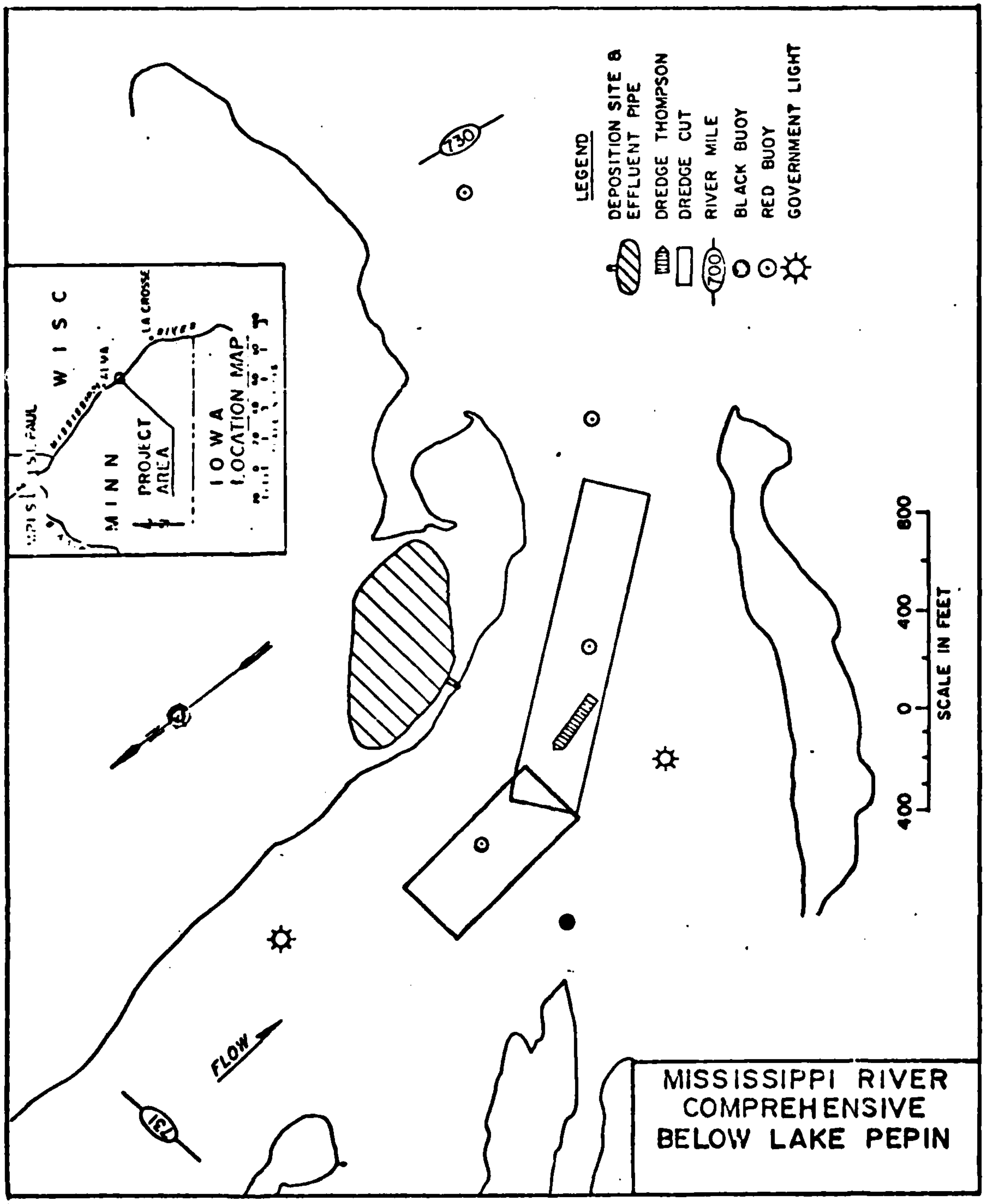


FIG. 1. Map of the Wild's Bend area of the Upper Mississippi River.

refrigerator (ca. 4^{o}C) until they could be processed. Samples were processed within 24 hr of collection.

Background water and sediment samples were collected on 19 September. Sediment samples were obtained from 8 sites within the proposed dredge cut (Fig. 2). Water samples were obtained from 5 sites overlying the proposed dredge cut (Fig. 2). Two samples, a surface water sample (0.3 m below the surface) and a bottom water sample (0.3 m above the bottom), were collected at all but 4 sites. These 4 sites were among those sampled on 22 September and were sampled at middepth only.

The effects of cutterhead disturbance were investigated on 21 September. Three sample sites (Con-W, Con-C, and Con-E) were established upstream to the dredge and they served as upstream control stations (Fig. 3). Two stations (25-W and 25-E) were established on either side of and 25-ft (7.6 m) downstream from the cutterhead (Fig. 3). Finally, 3 stations were established 600-ft (183 m) downstream to the cutterhead.

The efficacy of dredge effluent containment was assessed on 22 September by establishing stations as delineated in Fig. 4. Two control stations (Con-W and Con-C) were established upstream to the dredge and to the containment area. Cutterhead-associated effects were monitored by two stations (BW and BE) just downstream from the stern of the Thompson. Dredge effluent itself was also sampled as it left the effluent or dredge pipe. The water quality effects of effluent overflow (and possible seepage) from the containment structure were investigated by sampling 4 parallel transects that were 100-ft (30m), 200-ft (61 m), 300-ft (91 m), and 400-ft (122 m) downstream to the effluent pipe (Fig. 4). Three stations (W, C, and E) were established on each transect (Fig. 4). Two additional transects (950-ft and 1650-ft) were also established, but were inadvertently not sampled for

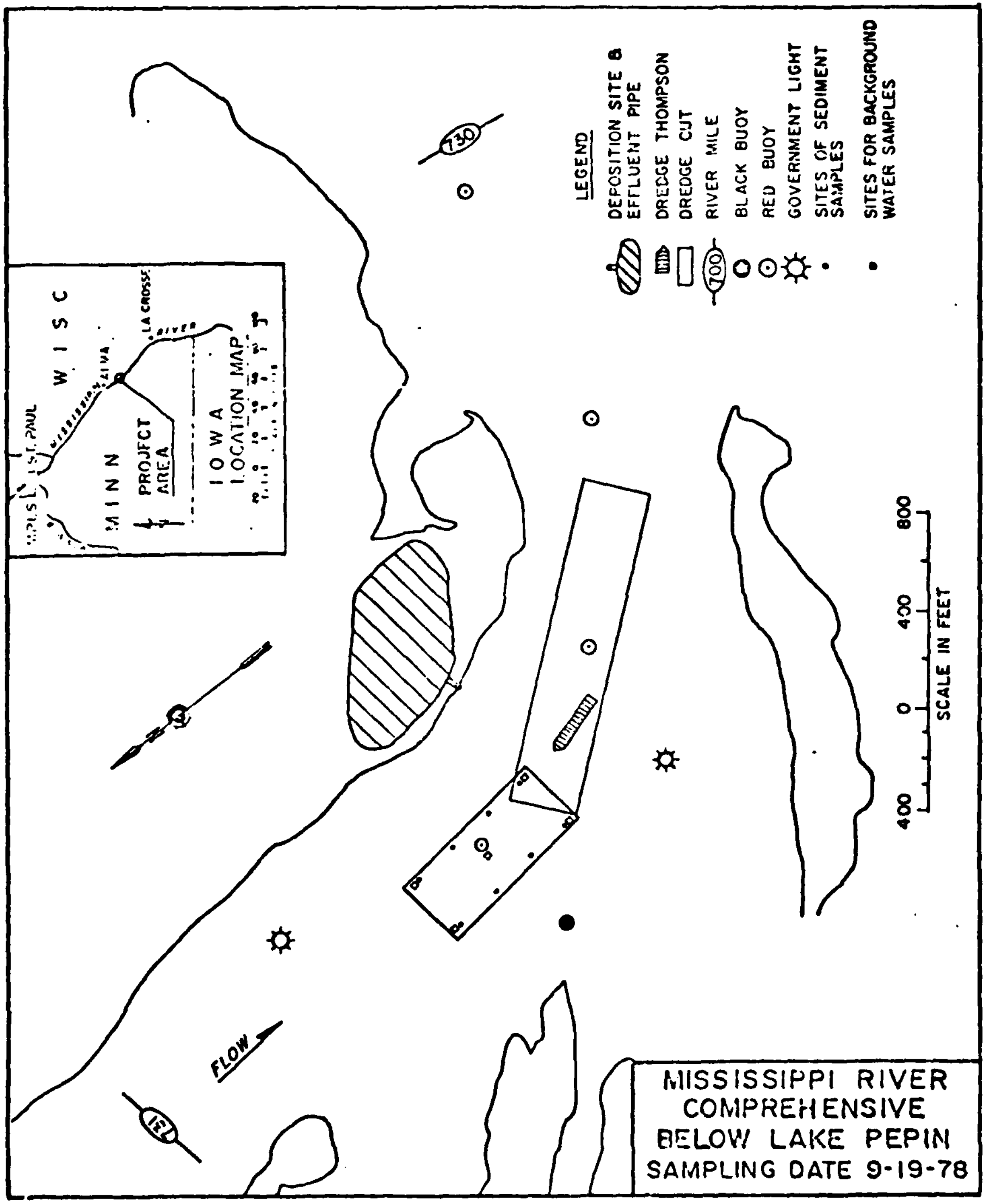


FIG. 2. Distribution of sampling sites on 19 September.

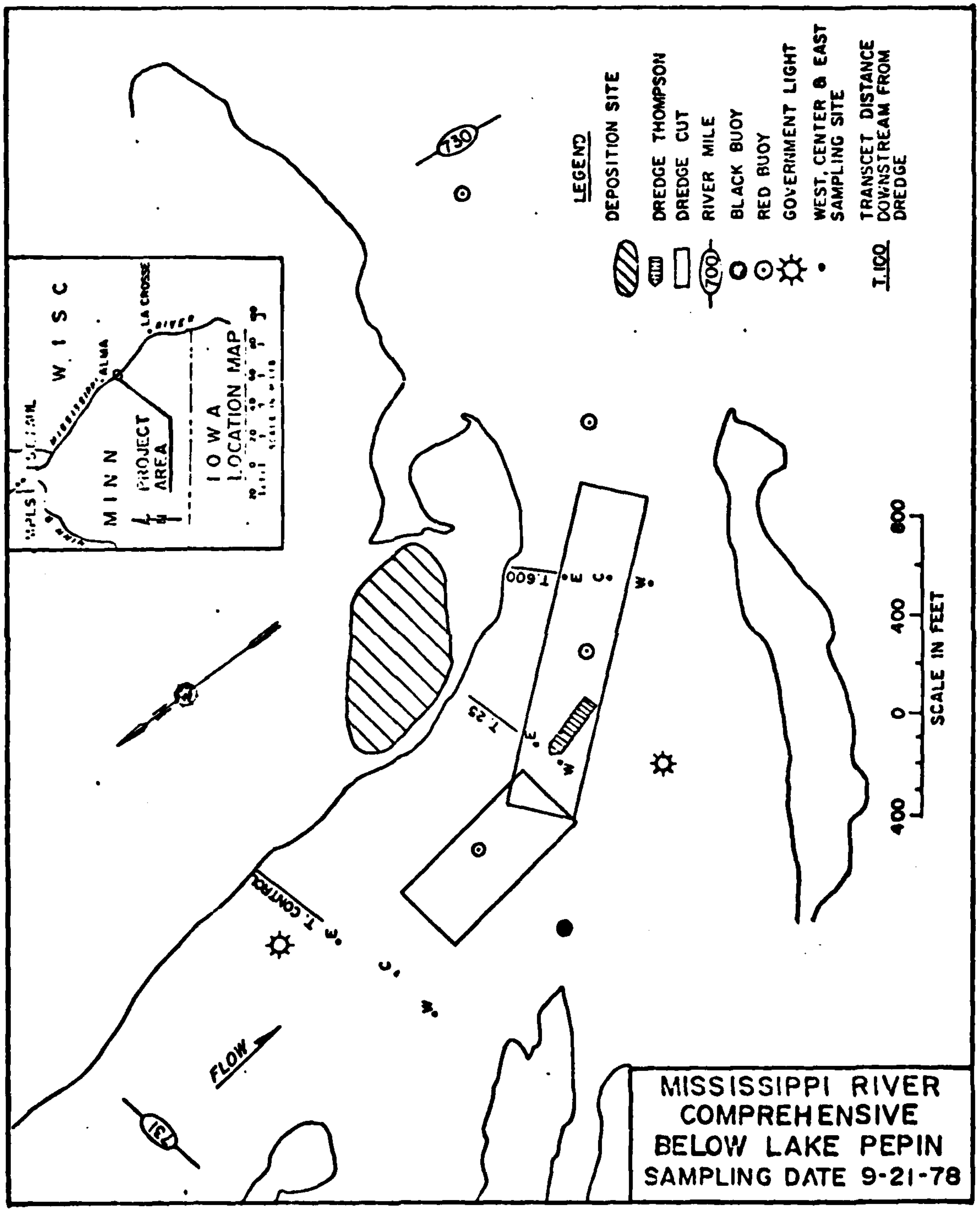


FIG. 3. Distribution of sampling sites on 21 September.

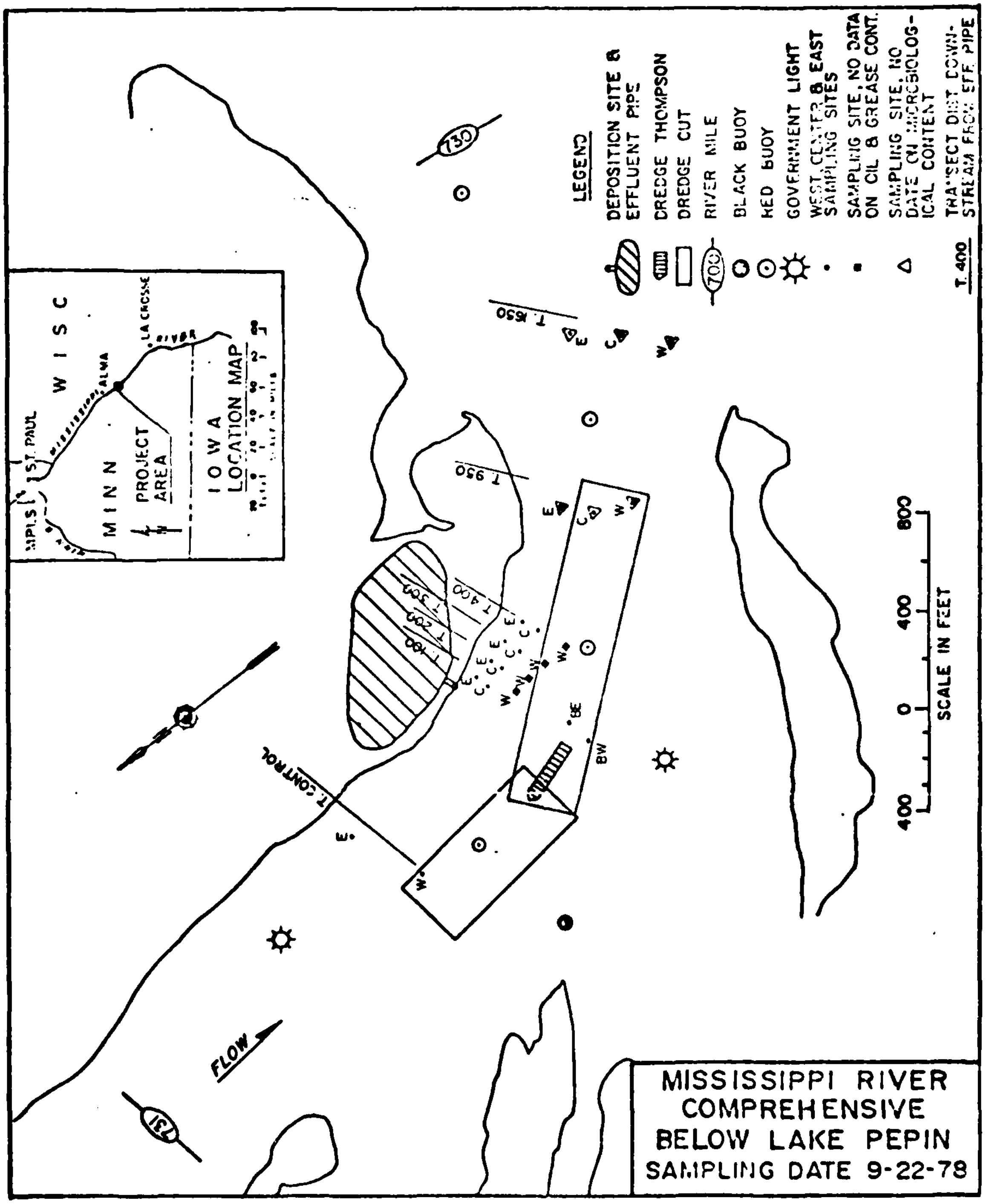


FIG. 4. Distribution of sampling sites on 22 September.

microbiological analysis.

Indicator bacteria. All water and sediment samples were analyzed for indicator bacteria by using standard techniques (1) as previously described (6). This included the use of type HC membranes (HCWG 047 S1, Millipore Corp., Bedford, MA 01730) for all phases of the study. Membrane filter analysis of sediment samples was accomplished by a modification of the elutriate test as described by the Environmental Protection Agency in 1975 (3). Our modification consisted of adding 20 g of each sediment sample to 80 ml of sterile phosphate buffer (1) contained in a sterile 250-ml Erlenmeyer flask. This slurry was vigorously mixed on a platform shaker for 30 min and then allowed to settle for 1 hr. The resultant liquid phase, or elutriate, was then subjected to membrane filter analysis for indicator bacteria. Recently, the elutriate test (3) has been refined (4), and the liquid phase we used for membrane filter analysis would be more correctly referred to as the suspended particulate phase (4).

Salmonella and shigella isolation. Water samples were examined for salmonellae and shigellae by broth enrichment of filtrates collected on glass fiber filters (A/E, Gelman Instrument Co.) over type HC membrane filters. Filtrates were collected by filtering 1-l volumes of water for each of the two enrichments. Since some of the water samples were very turbid, more than one glass filter-membrane pair often had to be used to effect filtration of 1 l. Sediment samples were analyzed for salmonellae and shigellae by placing 10 g of sediment into the appropriate broth enrichment medium. Salmonella enrichment was accomplished by placing glass filter-membrane pairs (representing 1 l of water filtered) or 10-g sediment samples into 125-ml Erlenmeyer flasks containing 50 ml of tetrathionate broth (Difco) modified by the addition of 20 mg

brilliant green per liter of broth. Flasks were incubated as stationary cultures at 41.5°C for 72 hr. Each brilliant green-modified tetrathionate broth was streaked onto plates of bismuth sulfite agar (Difco) and XLD agar (Difco) at both 24 and 72 hr and the plates were incubated at 35°C. Shigella enrichment utilized the standard technique (1) as modified by a suggestion from Geldreich (E.E. Geldreich, U.S. EPA, Cincinnati, personal communication). In this modification, water filtrates (glass filter-membrane pairs representing 1 l of water filtered) and sediment samples (10 g) were placed into 50 ml of nutrient broth (Difco) at pH 8.0 contained in 125-ml Erlenmeyer flasks and incubated as stationary cultures at 35°C for 6 hr. Nutrient broths were then streaked onto XLD agar plates which were incubated at 35°C.

Suspect colonies were picked from bismuth sulfite agar plates at 48 hr and from XLD agar plates at 24 hr, and were transferred to triple sugar iron agar slants (Difco). All alkaline/acid cultures were then biochemically classified using techniques (2) as previously described (6). Isolates giving reactions consistent with Salmonella and Shigella were then serologically grouped with Bacto-Salmonella O antisera (Difco).

RESULTS

Sediment samples. Sediments in the Wild's Bend area were composed of coarse sand and the results for the 8 samples (Fig. 2) are listed in Table 1. The indicator counts were very low and there were no salmonella or shigella isolations made from any sediment sample. Membrane filter densities were, in most cases, slightly higher than respective MPN indices. However, the small sample number (n=8) precluded meaningful statistical analysis of this possible difference. FC/FS ratios were generally indicative of mixed human

BLE 1. Indicator bacteria per gram (dry wt) of sediment[a].

Sample Location	Total Coliforms		Fecal Coliforms		Fecal Streptococci		FC/FS		Salmonella
	MPN[b]	mf[c]	MPN	mf	MPN	mf	MPN	mf	
1-East	9	5	2	12	1	3	2.0	4.0	No
1-West	4	35	2	2	1	2	2.0	1.0	No
2-East	6	19	5	1	2	3	2.5	0.3	No
2-West	20	65	1	12	1	3	1.0	4.0	No
3-East	1	6	1	1	0	1	-	1.0	No
3-West	4	49	4	3	1	3	4.0	1.0	No
4-East	3	26	2	2	1	1	2.0	2.0	No
4-West	41	37	3	2	1	3	3.0	0.7	No
$\bar{X}$	11	30	3	4	1	2	3.0	2.0	--

[a]Conversion of data to a wet-wt basis can be accomplished by dividing each value by 1.159.

[b]MPN indices based on 3 decimal dilutions of the sediment with 5 tubes per dilution.

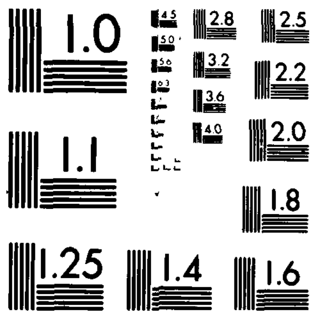
[c]Membrane filer (mf) colony forming units on Type HC membranes as determined by the elutriate test; arithmetic mean of 2 replicate determinations. See Appendix I for replicate values.

AD-A109 984 CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT F/G 13/2
AN ASSESSMENT OF WATER QUALITY IMPACTS OF MAINTENANCE DREDGING --ETC(U)
JAN 81 D D ANDERSON, R J WHITING, B JACKSON

UNCLASSIFIED NL

3 of 3

END
DATE
FILMED
3-82
DTIC



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

and animal fecal pollution (i.e., most were between 0.7 and 4.0).

Background water samples. Indicator bacteria densities in the background water samples collected on 19 September (Fig. 2) are listed in Table 2. The FC counts were generally greater than 400 per 100 ml, and the FC/FS ratios were indicative of mixed human and animal fecal pollution. Salmonellae, but no shigella, were isolated from 3 (25%) of the 12 samples; there were 11 salmonella isolates representing 2 serogroups. Comparison of the TC and FC densities in background water samples (Table 2) with corresponding densities in the upstream control samples collected on 21 September (Table 3) and on 22 September (Table 4) revealed no significant differences (Appendix V). Differences between the FS densities observed on the three sampling dates were, however, significant at the 1% level (Appendix V).

Experimental water samples. Indicator bacteria densities in the samples collected on 21 September (Fig. 3) are listed in Table 3. FC counts (Table 3) were slightly higher than those recorded for 19 September (Table 2). FS densities (Table 3) were lower than corresponding 19 September FS counts (Table 2). These opposing trends (i.e., increasing FC counts and decreasing FS counts) contributed to the higher FC/FS densities observed on 21 September (Table 3), most of which were greater than 4.0 and therefore indicative of human fecal pollution. A one-way analysis of variance between the upstream (control) concentrations of indicator bacteria and the downstream (below dredge cutterhead) densities revealed no significant differences (Appendix VI). There were no successful salmonella or shigella isolations made on 21 September (Table 3).

Table 4 lists the results of the 22 September sampling (Fig. 4). FC densities were still high (most were greater than 400), FS values were

TABLE 2. Background total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) densities[a] in water samples collected from the proposed dredge cut area (river mile 730.7) and from the Fountain City Wastewater Treatment effluent ditch (river mile 732.0) on 19 September 1978. Fecal coliform: fecal streptococcus ratios (FC/FS) and the presence or absence of salmonellae are listed for each sample.

Sample Location	Indicator Bacteria per 100 ml			$\frac{FC}{FS}$	Salmonella[b]	Serogroup
	TC	FC	FS			
B1-T	1600	410	140	2.0	No	
B1-B	1400	590	200	3.0	No	
B2-T	1200	480	120	4.0	Yes (3)	D
B2-B	1300	450	150	3.0	No	
B3-T	1300	390	150	2.6	Yes (6)[e]	B
B3-B	2000	610	160	3.8	No	
B4-T	1500	290	130	2.2	No	
B4-B	1100	360	130	2.8	Yes (2)	B
B5-T	1900	360	160	2.3	No	
B5-B	1400	400	120	3.3	No	
$\bar{X}$[c]	1470	434	146	2.9	--	
Effluent	2000	250	50	5.0	No	
Eff.-river[d]	1400	390	120	3.3	No	

[a]All values are arithmetic averages of 2 replicate determinations per sample. See Appendix II for replicate values.

[b]Parenthetic number indicates the number of serologically confirmed and grouped salmonellae.

[c]$\bar{X}$ = arithmetic mean of the 10 background samples.

[d]Sample collected from the confluence of the wastewater with the river.

[e]Two group B salmonellae were isolated from B3-T; 4 additional isolates that clumped strongly in Poly A-I antiserum would not agglutinate in selected factors (O antigens) representing the individual groups A through I. The 4 isolates were, in all probability, Salmonella enteritidis since they were lysine +, malonate -, gelatin -, lactose -, and sucrose -.

TABLE 3. Total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) densities[a] in water samples collected near the dredge on 21 September 1978. Fecal coliform:fecal streptococcus ratios (FC/FS) and the presence or absence of salmonellae are listed for each sample.

Sample Location[b]	Indicator Bacteria per 100 ml			$\frac{FC}{FS}$	Salmonella
	TC	FC	FS		
Con-W-T	2300	530	110	4.8	No
Con-W-B	1300	410	160	2.6	No
Con-C-T	1400	430	55	7.8	No
Con-C-B	2000	420	100	4.2	No
Con-E-T	780	430	110	3.9	No
Con-E-B	2100	500	65	7.7	No
25-W-T	1900	540	150	3.6	No
25-W-B	1400	470	120	3.9	No
25-E-T	1400	440	90	4.9	No
25-E-B	2300	480	90	5.3	No
600-W-T	1400	540	130	4.2	No
600-W-B	1800	420	120	3.5	No
600-C-T	1800	510	110	4.6	No
600-C-B	1400	420	75	5.6	No
600-E-T	1600	550	95	5.8	No
600-E-B	1900	480	110	4.7	No

[a]All values are arithmetic averages of two replicate determinations per sample. See Appendix III for replicate values.

[b]Location code: Con = above dredge control, W = west side of transect, C = center of transect, E = east side of transect, T = top, B = bottom, numbers = number of feet downstream from dredge cutterhead.

TABLE 4. Total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) densities[a] in water samples collected near the contained disposal site on 22 September 1978. Fecal coliform: fecal streptococcus ratios (FC/FS) and the presence or absence of salmonellae are listed for each example.

Sample Location[b]	Indicator Bacteria per 100 ml			$\frac{FC}{FS}$	Salmonella[c]	Serogroup
	TC	FC	FS			
Con-W-T	1100	530	55	9.6	Yes (5)	B
Con-W-B	1900	900	80	11.3	Yes (7)	B
Con-C-T	1200	480	65	7.4	No	
Con-C-B	1700	280	60	4.7	Yes (2)	B
BW-T	1100	570	45	12.7	No	
BW-B	1200	520	40	13.0	No	
BE-T	1100	460	80	5.8	No	
BE-B	880	530	55	9.6	No	
DP	1900	450	110	4.1	No	
100-W-T	<20	510	50	10.2	Yes (1)	B
100-W-B	2200	520	95	5.5	No	
100-C-M	1100	500	35	14.3	No	
100-E-M	1800	560	25	22.4	No	
200-W-T	2100	720	50	14.4	No	
200-W-B	2700	450	85	5.3	No	
200-C-M	1700	330	65	5.1	Yes (1)	C_1
200-E-M	550	440	60	7.3	No	
300-W-T	1800	-	30	-	Yes (4)	B
300-W-B	1800	2300	35	65.7	No	
300-C-T	2600	920	120	7.7	No	
300-C-B	1500	690	45	15.3	No	
300-E-T	2000	1000	45	22.2	No	
300-E-B	980	490	100	4.9	No	
400-W-T	980	600	25	24.0	No	
400-W-B	930	460	65	7.1	Yes (2)	B
400-C-T	2300	410	50	8.2	No	
400-C-B	1100	530	30	17.7	No	
400-E-T	1400	470	35	13.4	No	
400-E-B	2100	720	75	9.6	No	

[a]All values are arithmetic averages of 2 replicate determinations per sample. See Appendix IV for replicate values.

[b]Location code: Con = above dredge control, W = west side of transect, C = center of transect, E = east side of transect, T = top, M = mid, B = bottom, numbers = number of feet downstream from effluent pipe.

[c]Parenthetic number indicates the number of serologically confirmed and grouped salmonellae.

even lower than those observed on 21 September (Table 3), and all FC/FS ratios were greater than 4.0. Salmonellae, but not shigellae, were recovered from 7 (24%) of the 29 samples, and there were 22 total isolates representing 2 serogroups (Table 4). The upstream control stations accounted for 14 of the 22 salmonella isolations (Table 4). A one-way analysis of variance between upstream (control) concentrations, at-dredge concentrations (BW and BE samples, Fig. 4 and Table 4), and below containment concentrations of indicator bacteria revealed no significant differences (Appendix VI).

DISCUSSION

Background water samples (Table 2) revealed that the Wild's Bend reach of the Mississippi River was receiving fecal pollution. FC/FS ratios suggested that the nature of the pollution was mixed (i.e, animal and human fecal material). The sewage treatment plant at Fountain City appeared to have very little effect on area water quality, however, as evidenced by data in Table 2.

The background, or normal, microbiology of the river showed very little change during the study period. This was evidenced by a lack of significant difference (Appendix V) between indicator densities in the background samples (Table 2) and in the upstream control samples (Tables 3 and 4).

Sediment samples contained very few indicator bacteria (Table 1) and did not exhibit the relationship reported by Van Donsel and Geldreich (8). This relationship, that sediment fecal coliforms approximate 100 to 1000 times FC concentrations in the overlying water column, was observed in our previous study of hydraulic dredging (6).

The fact that the sediments contained few indicator bacteria and no salmonella or shigella probably explain the lack of effect (Appendix VI) that dredging had on water quality during the study. While dredge effluent containment may have prevented water-borne contaminants from reentering the river, there still should have been some detectable, dredge-associated water-quality effects within close proximity of the cutterhead (Table 3). Since there were none, it can only be assumed that the data (Tables 3 and 4 and Appendix VI) reflect the results of dredging microbiologically clean sediment. Therefore, Objective 3 of this study, "to determine the ability of a containment structure to minimize the impact of hydraulic dredge effluent on river water quality as measured by TC, FC, and FS bacteria", cannot be answered with the data (Table 4 and Appendix VI).

CONCLUSION

It is unfortunate that the sediments proved to be so clean that they did not permit evaluation of dredge effluent containment on microbiological water quality. In theory, containment is microbiologically sound. The major portion of dredged sediment, including sediment-bound bacteria, should be held within the containment structure. In addition, since containment structures (including the one in this study) are usually composed of sand, any seepage water, or percolate, reentering the river should be of better microbiological water quality than the river itself. This is because the containment pit would act as a sand filter, and the efficiency of sand filters for certain types of sewage treatment is well established.

LITERATURE CITED

1. American Public Health Association. 1976. Standard methods for the examination of water and wastewater, 14th ed. American Public Health Assoc., Washington, D. C.

2. Edwards, P. R., and W. H. Ewing. 1972. Identification of enterobacteriaceae, 3rd ed. Burgess Publishing Co., Minneapolis.

3. Environmental Protection Agency. 1975. Navigable waters. Discharge of dredged or fill material. Federal Register. 40(173): 41291-41298.

4. Environmental Protection Agency/U.S. Army Corps of Engineers. 1977. Ecological evaluation of proposed discharge of dredged material into ocean waters. Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

5. Grimes, D. J. 1975. Release of sediment-bound fecal coliforms by dredging. Appl. Microbiol. 29: 109-111.

6. Grimes, D. J. 1977. Microbiological water quality effects of hydraulically dredging polluted bottom sediments in the Upper Mississippi River. I. Resuspension of bacteria. Mimeographed report to the Water Quality Work Group of GREAT, River Studies Center, University of Wisconsin-La Crosse, La Crosse, WI.

7. Grimes, D. J. 1978. Microbiological water quality effects of clamshell dredging bottom sediments from the Upper Mississippi River. Mimeographed report to the Water Quality Work Group of GREAT, River Studies Center, University of Wisconsin-La Crosse, La Crosse, WI.

8. Van Donsel, D. J., and E. E. Geldreich. 1971. Relationships of salmonellae to fecal coliforms in bottom sediments. Water Res. 5: 1079-1087.

APPENDIX I.

Indicator bacteria per gram (dry wt) of sediment.

Sample Location	Total Coliforms			Fecal Coliforms			Fecal Streptococci		
	Rep 1	Rep 2	$\bar{x}$	Rep 1	Rep 2	$\bar{x}$	Rep 1	Rep 2	$\bar{x}$
1 - East	7	2	5	5	19	12	3	3	3
1 - West	42	28	35	2	2	2	3	1	2
2 - East	28	9	19	1	1	1	1	5	3
2 - West	70	60	65	7	17	12	3	3	3
3 - East	7	5	6	2	0	1	2	0	1
3 - West	46	51	49	3	3	3	4	1	3
4 - East	37	14	26	2	2	2	2	0	1
4 - West	23	51	37	1	3	2	3	3	3

APPENDIX II.

Indicator bacteria per 100 ml of background samples collected on 19 September 1978.

Sample Location	Total Coliforms			Fecal Coliforms			Fecal Streptocci		
	Rep 1	Rep 2	$\bar{x}$	Rep 1	Rep 2	$\bar{x}$	Rep 1	Rep 2	$\bar{x}$
B1 - T	1250	1900	1600	430	380	410	180	90	140
B1 - B	1400	1400	1400	660	520	590	140	250	200
B2 - T	850	1550	1200	520	440	480	100	140	120
B2 - B	1650	1000	1300	400	500	450	130	170	150
B3 - T	1200	1400	1300	290	480	390	130	160	150
B3 - B	2200	1750	2000	770	440	610	200	110	160
B4 - T	1750	1300	1500	180	390	290	160	100	130
B4 - B	1250	1000	1100	320	400	360	100	150	130
B5 - T	2200	1500	1900	390	320	360	140	180	160
B5 - B	1400	1400	1400	340	460	400	120	120	120
Effluent	1250	2700	2000	200	300	250	20	80	50
Effl.-river	1000	1750	1400	320	450	390	100	130	120

APPENDIX III.

Indicator bacteria per 100 ml of water samples collected on 21 September 1978.

Sample Location	Total Coliforms			Fecal Coliforms			Fecal Streptococci		
	Rep 1	Rep 2	$\bar{x}$	Rep 1	Rep 2	$\bar{x}$	Rep 1	Rep 2	$\bar{x}$
Con-W-T	2300	2200	2300	500	560	530	110	110	110
Con-W-B	1250	1400	1300	400	420	410	120	200	160
Con-C-T	1000	1800	1400	440	410	430	50	60	55
Con-C-B	2150	1850	2000	460	380	420	80	120	100
Con-E-T	1000	560	780	430	430	430	90	130	110
Con-E-B	2400	1700	2100	550	450	500	80	50	65
25-W-T	1250	2500	1900	520	560	540	120	180	150
25-W-B	1450	1250	1400	460	480	470	110	120	120
25-E-T	1550	1300	1400	480	400	440	40	140	90
25-E-B	2050	2550	2300	440	520	480	60	120	90
600-W-T	1500	1350	1400	520	560	540	120	130	130
600-W-B	1950	1650	1800	540	300	420	100	140	120
600-C-T	1850	1800	1800	500	510	510	100	110	110
600-C-B	1500	1250	1400	460	380	420	60	90	75
600-E-T	1600	1550	1600	580	520	550	80	110	95
600-E-B	2000	1800	1900	410	550	480	110	100	110

APPENDIX IV.

Indicator bacteria per 100 ml of water samples collected on 22 September 1978.

Sample Locations	Total Coliforms			Fecal Coliforms			Fecal Streptococci		
	Rep 1	Rep 2	$\bar{x}$	Rep 1	Rep 2	$\bar{x}$	Rep 1	Rep 2	$\bar{x}$
Con-W-T	800	1300	1100	540	520	530	60	50	55
Con-W-B	2750	1050	1900	920	880	900	110	50	80
Con-C-T	1450	850	1200	520	440	480	50	80	65
Con-C-B	1750	1650	1700	320	240	280	40	80	60
BW-T	1250	850	1100	500	640	570	70	20	45
BW-B	900	1500	1200	510	520	520	60	20	40
BE-T	1200	1050	1100	460	460	460	70	90	80
BE-B	800	950	880	500	560	530	60	50	55
DP	1950	1800	1900	440	460	450	120	90	110
100-W-T	0[a]	0	<20	540	470	510	50	50	50
100-W-B	2300	2050	2200	580	460	520	110	80	95
100-C-M	950	1200	1100	480	520	500	30	40	35
100-E-M	1950	1550	1800	520	600	560	30	20	25
200-W-T	1700	2500	2100	780	660	720	30	70	50
200-W-B	2350	3000	2700	460	440	450	70	100	85
200-C-M	1650	1650	1700	330	330	330	50	80	65
200-E-M	500	600	550	490	390	440	70	50	60
300-W-T	1800	1880	1800	TNTC[b]	TNTC	TNTC	20	40	30
300-W-B	2300	1350	1800	2260	2320	2300	10	60	35
300-C-T	2700	2450	2600	860	980	920	140	90	120
300-C-B	1300	1760	1500	440	940	690	50	40	45
300-E-T	2500	1450	2000	1140	860	1000	10	80	45
300-E-B	1100	850	980	520	460	490	70	130	100
400-W-T	650	1300	980	580	620	600	10	40	25
400-W-B	1100	750	930	460	460	460	70	60	65
400-C-T	2050	2450	2300	420	400	410	60	40	50
400-C-B	950	1150	1100	620	440	530	40	20	30
400-E-T	1300	1500	1400	470	470	470	40	30	35
400-E-B	1700	2500	2100	760	680	720	70	80	75

[a]No colonies formed on 2 plates representing 5-ml filtration volumes.

[b]TNTC = Colonies "too numerous to count" with any accuracy.

APPENDIX V.

One-way analysis of variance between the mean indicator bacterial densities per 100 ml of upstream control samples.

Sampling Period	$\bar{X}_{TC}$	$\bar{X}_{FC}$	$\bar{X}_{FS}$	n
19 September	1467.5	431.5	143.5	20
21 September	1634.2	452.5	100.0	12
22 September	1450.0	547.5	65.0	8
n	40	40	40	--
F[a]	0.50	1.90	13.63	--

[a] $F^{0.01}_{2,37} = 7.37$ (i.e., the probability of a F-value exceeding 7.37 as a result of simple random sampling a normal population is less than 0.01).

APPENDIX VI.

One-way analysis of variance between mean indicator bacterial densities per 100 ml.

Sample Location	21 September 1978			22 September 1978		
	$\bar{X}_{TC}$	$\bar{X}_{FC}$	$\bar{X}_{FS}$	$\bar{X}_{TC}$	$\bar{X}_{FC}$	$\bar{X}_{FS}$
Upstream control	1634.2	452.5	100.0	1450.0	547.5	65.0
At dredge	ND[a]	ND	ND	1062.5	518.8	55.0
Downstream	1685.0	484.5	107.0	1663.5	652.8	58.1
F	0.09	1.77	0.29	3.49	0.60	0.24
d.f., numerator	1	1	1	2	2	2
d.f., denominator	30	30	30	53	53	55
Rejection F[b]	7.56	7.56	7.56	5.03	5.03	5.01

[a]ND - not done

[b]The probability is less than 0.01 that a F-value will exceed this number if the null hypothesis, that the sample means are equal, is true.

8

DTIC